MIDDLE JURASSIC AMMONITES OF TIBET AND THE AGE OF THE LOWER SPITI SHALES

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ABSTRACT. Middle Jurassic ammonites of China are known only from Tibet. Eighteen localities are described, some new. Only Lower Bajocian and Lower–Middle Callovian are established, whereas the other Middle Jurassic stages or substages are usually represented by hiati or non-marine facies. Two major ammonite faunas are distinguished: (1) *Witchellia–Fontannesia* Association, including *Fontannesia kiliani* ['*Dorsetensia*' auct.], Laeviuscula Zone, known from the central part of Tethyan Himalaya and with strong affinity to northern and western Australasia of the extreme south-east Tethys; (2) '*Grayiceras*' Association, including *Grayiceras*? *gucuoi* n. sp., late Calloviense Zone (*Subkossmatia opis* Assemblage Zone of Kachchh), possibly widely distributed in the basal Spiti Shales (*Belemnposis gerardi* Beds) and equivalents of Tethyan Himalaya, to which it appears to be largely endemic, together with rare Indo-Madagascan (Ethiopian) and Mediterranean elements. In addition, the Early Bajocian Discites and ?Sauzei–Humphriesianum Zones, and the Middle Callovian Coronatum Zone are indicated locally.

The '*Grayiceras*' fauna was dated as Oxfordian by most previous authors, but the stage is missing at least locally in South Tibet, where Kimmeridgian lies conformably on Lower Callovian. Biogeographic affinities support an origin of the Tethyan Himalaya from the Gondwana margin, not too distant from northern Australasia, whereas the limited North Tibetan faunas are consistent with a Eurasian position.

MIDDLE Jurassic marine strata and ammonites of China are more widespread than those of the Early or Late Jurassic. Their study began only recently (Zhao 1976), except for Arkell's (1953) record of a small Middle Bajocian ammonite fauna collected by H. Hayden at Mekyigunru, Gamba county in the Tethyan Himalaya of South Tibet (our loc. 1; text-fig. 1). Subsequently, Wang and Chen (in Wang *et al.* 1979) reported several Middle Jurassic ammonite species from North Tibet, and Yang (unpublished) recognized several Callovian specimens from South Tibet. The genera and species recorded in these papers are here revised, despite the poor and incomplete preservation of the fossils, and recent stratigraphic data about the ammonite-bearing localities are discussed. Some of the ammonite collections, however, lack strict stratigraphic control, while others which are stratigraphically controlled remain inadequate because of their small sample size and poor preservation. In 1985, we re-examined two important sections (locs. 2 and 13) and made additional fossil collections with good stratigraphic control.

Since plate-tectonic theory holds that the Tethyan Himalaya is part of the Indian Plate of Gondwana, whereas North Tibet was part of Eurasia in the Jurassic, the present data, from both areas, are a significant contribution to the palaeogeography and ammonite biogeography of the Middle Jurassic in western China and central Asia.

In the classic Spiti–Niti area in the western Himalaya (see text-fig. 1), the Lower Spiti Shales or *Belemnopsis gerardi* Beds, and the Ferruginous Oolite have been the subject of recent investigations. Based on new ammonite evidence, the basal oolites representing the transgressive phase belong to different parts of the Callovian with strong lateral diachroneity (Jadoul *et al.* 1985). Latex casts of this small fauna have been made available to Westermann by M. Gaetani while this paper was in press. The '*Pachyceras* sp. ind.', the only evidence for alleged Upper Callovian is a Middle Callovian *Erymnoceras* (confirmed by A. Zeiss); the '*Macrocephalites* sp. ind.' is a *Grayiceras*? *waageni* (Uhlig), of top Lower Callovian age. The *B. gerardi* Beds yielded no new ammonite fauna. They were dated as Oxfordian–Kimmeridgian mainly by stratigraphic interpolation (Jai Krishna and Singh 1982) and by correlation with Indonesia, based on specifically unidentified belemnites and inoceramids. This homeotaxis, however, has turned out to be controlled by biofacies rather

TEXT-FIG. 1. Middle Jurassic ammonite localities and principal tectonic subdivision of Tibet. The Bangong Co-Nujiang (Tanggula) Deep Fracture Zone, with the Jurassic Ophiolite Flysh Belt (solid black), separates North from South Tibet; the Yarlung Zangbo Deep Fracture Zone (continuation of Indus Suture) with the Cretaceous Ophiolite Flysh Belt, divides South Tibet from the Tethyan Himalaya. See also Table 1.

than the biozones of these long-ranging taxa. The only known ammonites from the *B. gerardi* Beds appear to be the few specimens from the Spiti area described and discussed long ago by Uhlig (1903–1910). They have usually been identified and/or correlated with the Oxfordian mayaitid assemblage of Indonesia and the Indo-Madagascan (Ethiopian) Province (Uhlig 1910*b*; Spath 1925, 1927–1933; Arkell 1956). The other fauna of the Ferruginous Oolite has not been described or illustrated so that even generic identifications, sometimes made by non-specialists, cannot be trusted. This includes the supposed macrocephalitids which could be misidentified '*Grayiceras*'. Similar faunas were recorded from the central Himalaya of Nepal (Bordet *et al.* 1971). Here the basal sandstones and/or ferruginous oolites are said to contain Callovian ammonites, and the Lower Spiti Shales may be developed in ammonite-bearing facies, yielding what appears to be the first good evidence of the Oxfordian, i.e. *Perisphinctes* spp. found loose.

The Menkatun Formation of the South Tibetan Tethyan Himalaya is clearly the continuation of the Spiti Shales (and thus a superfluous term in the senior author's opinion) and, similarly, has at its base the Ferruginous Oolite which we would prefer to consider as a member of the 'Menkatun'/Spiti Shales Formation. Here the basal part of the shales is developed in ammonite-bearing facies containing the '*Grayiceras*' Assemblage here described, followed by poorly fossiliferous beds yielding the rare Kimmeridgian bivalve *Australobuchia spitiensis*. Most of the Callovian and the entire Oxfordian are missing.

THE MIDDLE JURASSIC GEOLOGY OF WESTERN CHINA
AND PLATE TECTONICS

In the conventional 'fixist' tectonic view, the Jurassic seas of China were evidently extensions of Tethys and Panthalassa, the ancient Pacific Ocean. The vast area of the Tibet-Qinghai Plateau (text-fig. 1), the most important Jurassic marine basin of China, was inundated from Tethys. Owing to the global regression at the end of the Triassic and the Indochina Orogeny, the Kunlun Mountains and their eastern extension into central Qinghai, the Hengduan Mountains, and the Yunnan–Guizhou Plateau became land. The coastline of the northern continent in China territory had shifted southward, approximately to a line from the Kunlun to the Hengduan Mountains, and most of the area south and west of this line received marine Jurassic deposits. We follow Wang and Sun (1983) in the divisions of the Jurassic sedimentary basins, as follows (from south to north, with the former designation by Wang and Sun in parentheses): Tethyan Himalaya District (District $I_1 + I_2$); Lhasa District (District I_3); Qamdo District (District I_7); Denquen-Shiquanhe District (District $I_4 + I_5$); Karakorum–Tanggula District (District I_6). Our localities lie almost exclusively in the Qamdo and Tethyan Himalaya districts.

The recent 'mobilistic' view based on plate-tectonic theory has greatly changed the reconstructions of Mesozoic southern Eurasia (Laurasia) as well as of Gondwana on the opposite side of Tethys (text-fig. 2). Much of southern and south-eastern Asia is a collage of continental blocks which assembled sequentially from the latest Palaeozoic to the Palaeogene. A variety of geologic histories for Tibet has been suggested in recent years (*in* Liu *et al*. 1981). One of the most lucid and most recent reconstructions is that of Sengör (1984, 1985). Text-figure 3 shows our modification of Sengör's palinspastic map for the later part of the Jurassic, with north-eastern Gondwana according to Hamilton (1979, 1983) and the Somali Basin already open (Westermann 1975; Rabinowitz *et al*. 1983; Bosellini 1986). The more northerly position of the Indian Shield provides room for the terranes in the Indian Ocean, a few of them proven but most of them controversial, and improves the biogeographic 'fit' of Permian to Jurassic Himalayan faunas with those of the northern Australasian margin (eastern Indonesia–New Guinea, etc.). The age of the Jurassic magnetic 'quiet zone', when Madagascar is said to have separated from Africa, is now extended downward from Callovian–Oxfordian to Bajocian (Ogg and Steiner 1985, and pers. comm.), and abundant Bajocian oceanic ammonoids at Mombasa (Westermann 1975) indicate pre-Bajocian separation. Dominance of 'leiostracan' ammonoids implies proximity of a deep ocean, rather than a shallow embayment caused by crustal stretching. An alternative possible position for the Tethyan Himalaya is proposed in text-fig. 3.

A rather similar Jurassic reconstruction of the northern margin of the Indian Shield to that of Hamilton's is provided by Johnston and Veevers (1984, fig. 14). They double the size of the shield so that it extends along both Antarctica and western Australia, but the Himalayan basin remains in the conventional southern position. This vast added area is similar in size to the entire Tibet–Qinghai Plateau, but no significant underthrusting of southern continental blocks occurred beneath Eurasia; the thick ophiolite series of the Yarlung Zangbo Suture dips southward.

According to Sengör (1984, 1985), the Cimmerian Continent, including the later North and South Tibet terranes, became separated from northern Gondwana at the end of the Palaeozoic. While moving northward across Tethys, this elongate palaeocontinent split lengthwise into two

parts (text-fig. 3). The northern part was assembled with Laurasia in the Early Mesozoic, thus closing the original Tethyan ocean (Palaeo-Tethys). Suturing occurred along the Lancan Jiang subduction zone (text-fig. 2). Northern Cimmeria is today the Cimmerides Orogenic Belt ranging from the Caucasus to Indo-china and includes the North Tibetan Qamdo terrane with our localities 5, 6, 12, 17, and 18 near or at its southern margin.
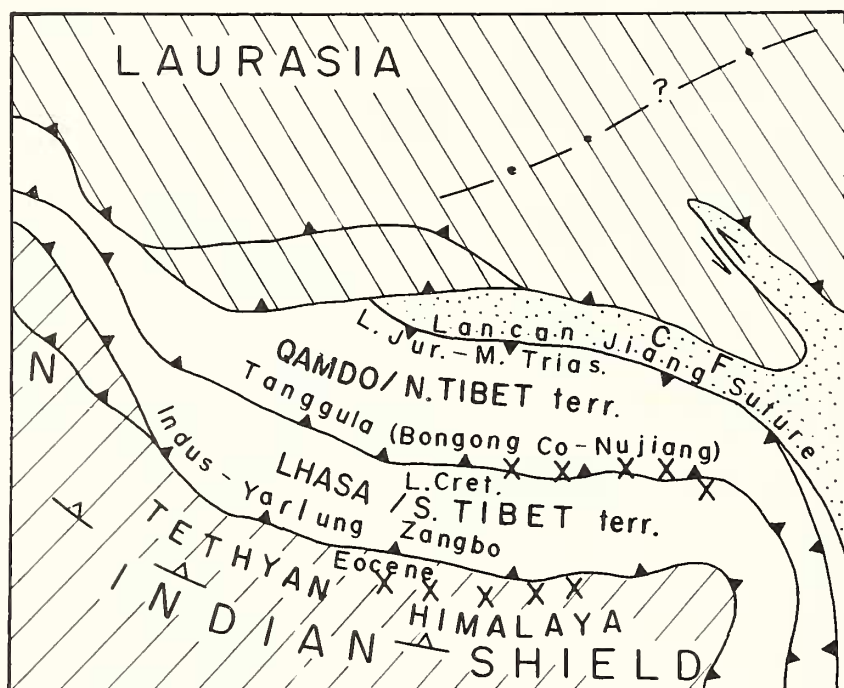
TEXT-FIG. 2. General tectonic map of Tibet according to Sengör (modified from Sengör, 1984, 1985) showing the principal sutural zones with time of closing, the major tectonostratigraphic terrane (blocks), and the Middle Jurassic localities (X). CF (stippled) = Cimmerian flysh fill on oceanic crust: Palaeo-Tethys (closed); N = Niti area. Qamdo is also spelled Qantang. Same area as text-fig. 1.

During the Middle and Late Jurassic the Tanggula Ocean separated the southern parts of Cimmeria (the later South Tibetan or Lhasa Block) from Eurasia (text-fig. 3). The Early Cretaceous subduction of the Tanggula Ocean along the margin of the Qamdo terrane closed this small ocean and welded the last part of Cimmeria to Laurasia/Eurasia. Since Sengör's map is for the Late Jurassic, the Bajocian–Callovian Tanggula Ocean was probably somewhat larger than shown here. Loc. 7, the only locality on the north-eastern margin of the South Tibet or Lhasa terrane, yielded only a small fauna not seen by us. The early Cretaceous suture is along the Tanggula (Bongong Co-Nujiang) Suture (Fracture Zone) (text-fig. 2).

The Indus–Yarlung Zangbo Fracture (Suture) defines the southern margin of the Lhasa terrane, marking the Eocene collision of the Indian Shield and the closure of Neo-Tethys. The Himalaya belongs to the Alpide Orogenic Belt stretching from the Mediterranean to Indonesia. Most of our localities, i.e. in the Tethyan Himalaya, are from near the northern shore (and ?slope) of the Indian Shield, now the western end of the Indo-Australian Plate (but see text-fig. 3).

TEXT-FIG. 3. The Middle to Late Jurassic position of the continents. A, according to Sengör (1984, 1985) for south-eastern Eurasia, and modified after Hamilton (1979 and see text), for the India–Madagascar region. B, the alternative, conventional position of the India–Madagascar region. Crosses indicate the Tibetan Middle Jurassic localities. A third alternative is here tentatively proposed: the Tethyan Himalaya was a terrane separated from the Indian Shield, lying alone in a more northern, west–east position. G, Geraldton district of Western Australia; M, Moluccas; NG, New Guinea; SN, Spiti–Niti area; B, Broken Ridge; K, Kerguelen Plateau; N, Naturalista Platcau; S, Seychelles Plateau. The ammonoid provinces, or subprovinces of Indo-W. Pacific Province and oceanic ridge with extension, are indicated.

TABLE 1. Middle Jurassic ammonite localities of Tibet (see also text-fig. 1).

	Tethyan Himalaya, South Tibet									Qamdo Block, North Tibet				
Locality	1	2	3	8	9	10	11	13	14	5	6	12	17	18
Unit/bed		6	1 u	1·2 4·6		1·6 7·13 14 18		2 3						12
Somuina s.l. sp.										+	+			
Euhoploceras cf. *subdecorata*	+													
Witchellia cf. *australica*	+	+												
W. tibetica	+													
W. cf *sutneri*		+												
Dorsetensia cf. *romani*										+				
Fontannesia kiliani	+	+												
F. haydeni	+													
F. ? cf. arabica			+											
Oxycerites n. sp. A			+											
Jeanneticeras cf *anomalum*								+						
Pseudotoites? cf. *sphaeroceroides*	+													
Macrocephalites cf. *macrocephalus*														+
M.? cf *etheridgei*				+										
(?)Grayiceras nepaulense								+ +						
G.? waageni				+	?	+		? +	+					
G.? gucuoi					?	+		+						
Subkossmatia cf. *opis*								+ +						
Erymnoceras aff. *coronatum*							+							
Choffatia cf. *madani* and *balinensis*					+	+								
C. cf. *funiota*								+				+	+	+
C. propinqua								+						
C. (Indosphinctes) aff. *urbana*												+		

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	Tethyan Himalaya, South Tibet										Qamdo Block, North Tibet				
Locality	1	2	3	u	8	9	10	11	13	14	5	6	12	17	18
Unit/bed	6	1			1-2 4-6		1-6 7-13 14-18			2 3			12		
Somninia s.l. sp.	+										+				
Euhoploceras cf. *subdecorata*	+	+													
Witchellia cf. *australica*	+	+													
W. tibetica		+													
W. cf. *sutneri*		+									+				
Dorsetensia cf. *romani*	+	+										+			
Fontannesia kiliani	+														
F. haydeni	+														
F. ? cf. *arabica*			+												
Oxycerites n. sp. A				+											
Jeanneticeras cf. *anomalum*	+														
Pseudotoites? cf. *sphaeroceroides*									+						
Macrocephalites cf. *macrocephalus*					+										
M.? cf. *etheridgei*							+								
(?)*Grayiceras nepaulense*						+			+	+					
G.? *waageni*						?			?	+					
G.? *gucuoi*						?	+		+	+					
Subkossmatia cf. *opis*								+							
Erymnoceras aff. *coronatum*							+								
Choffatia cf. *madani* and *balinensis*							+								
C. cf. *funata*													+		+
C. propinqua													+	+	
C. (*Indosphinctes*) aff. *urbana*														+	+

AMMONITE LOCALITIES

Localities that have yielded ammonites are summarized in Table 1.

Bajocian localities

The ammonite faunas described by Arkell (1953), Wang (*in* Zhao 1976), and Wang and Chen (*in* Wang *et al.* 1979) are from three localities in the Tethyan Himalayan District of South Tibet (locs. 1–3), and one in the Denquen-Shiquanhe District of North Tibet (loc. 6). Two additional localities have not been described previously (locs. 4 and 5) and two (locs. 2 and 13) were re-examined by us (text-fig. 1).

The Tibet-Qinghai Plateau is the only known area in China with Bajocian ammonites. Arkell (1953) attached great importance to the Bajocian ammonite fauna from 'Kampadzong' in Gamba (loc. 1): 'the Tibetan occurrence is the only known link (besides the little known one in the Pamir) between the Bajocian occurrences of East and West Asia.' Subsequently, scientific expeditions organized by the Academia Sinica to the Mount Jolmo Lungma (Mount Everest) Region and its vicinity in 1966–1968 and to the vast area of the Tibet-Qinghai Plateau in 1973–1976 found some new localities with Bajocian ammonite faunas.

Alleged Bathonian localities

No Bathonian ammonites have been discovered in China. In the Tibet-Qinghai Plateau an alleged *Delecticeras* (Oppeliidae) was recorded from Niejia, Kangmar County in the Tethyan Himalaya by D. Yang (unpubl.). The true Late Bathonian *Delecticeras* has a tricarinate-bisulcate venter, but Yang's specimen appears to be bicarinate-trisulcate. The Tibetan specimen also has a rather simple, subammonitic septal suture. We suggest therefore that Yang's specimen might be a Triassic *Dittmarites*.

Callovian localities

The marine transgression reached its maximum extent in the Tibet-Qinghai Plateau during the Callovian, and thirteen localities (locs. 3, 7–18) are now known. The ammonites from localities 8, 10, and 11 were first described by Zhao (1976); those from locality 9 were found by D. Yang (unpubl.); the small fauna from locality 12 was reported by Wang and Chen (*in* Wang *et al.* 1979). We revise them below.

Locality 1. Mekyigunru, about 13 km south of Gamba County, Tethyan Himalaya. This is the classical locality (formerly Kampadzong) of Hayden (1907) and Arkell (1953). The fauna was collected from the highest beds of the Lungma Limestone which is about 17 m thick (Hayden 1907), but without detailed stratigraphic control. Judging from the revised faunal list (Table 1) only the lower Bajocian Discites and Laeviuscula Zones are established (*Euhoploceras*, *Witchellia*, *Fontannesia*).

Arkell's (1953) '*Frogdenites*' is now tentatively classified as *Pseudotoites*, a Pacific genus of the Laeviuscula Zone. Our *Witchellia* cf. *australica* Arkell closely resembles the species originally found in the Newmarracarra Limestone of Western Australia in the same zone, whereas *W. tibetica* Arkell is very close to '*Zugophorites*' *zugophorus* Buckman from the Ovalis Subzone, lower Laeviuscula Zone, of England. In Europe, *Fontannesia* and *Euhoploceras* are both limited to the topmost Aalenian and the Discites Zone, basal Bajocian, but the former occurs in the Laeviuscula Zone of Australia.

Locality 2. Pupuga, 2 km east of Tulong, Nyalam County, Tethyan Himalaya (Wang *et al.* 1974; Wang *in* Zhao 1976); see text-fig. 4. The fauna from two horizons (colls. Jsb 79 and Jsb 73) of one section was collected by Wang, Chang and co-workers in 1966 (Wang and Chang 1974). We have re-collected at Jsb 79 in unit 6 of the Niehnieh Hsiungla Formation (text-fig. 5).

The upper 98 m of unit 6 consists of grey medium-bedded or thick-bedded limestone alternating with argillaceous limestone. A 1–2 m thick bed of bioclastic sandstone has yielded *F. kiliani* (Kruizinga), *W.* cf. *australica* Arkell, *W.* cf. *sutneri* (Branco), and brachiopods. The lower 37 m of the unit is greyish black limestone.

The lower half of unit 4 consists of 182 m of grey-black, medium-bedded limestone intercalated with quartz sandstone. It yielded '*Dorsetensia xizangensis*' Wang (coll. Jsb 73), an unidentifiable (?) hildoceratid.
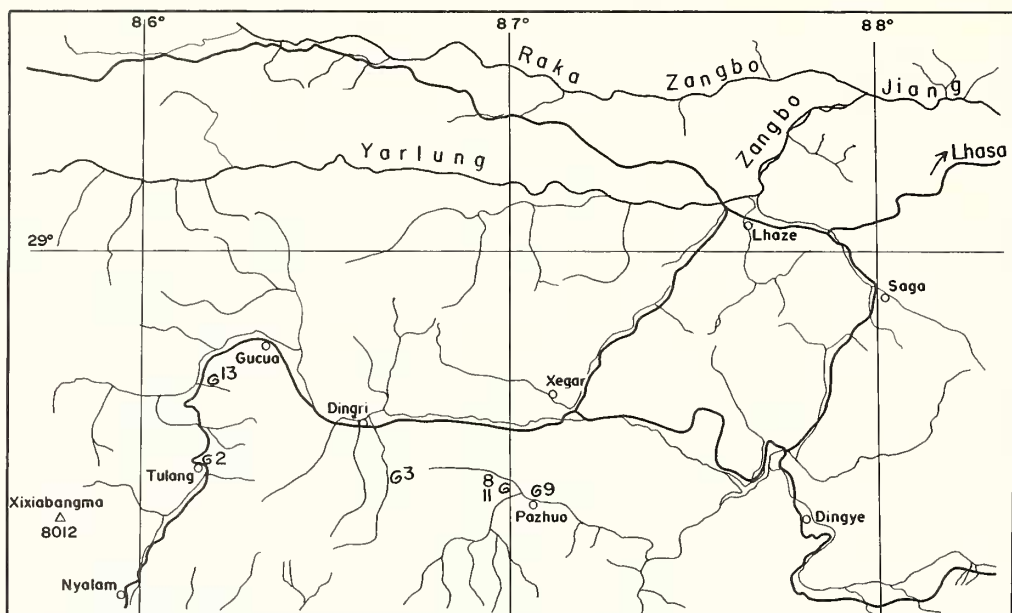
TEXT-FIG. 4. Map showing the most important Middle Jurassic ammonite localities, in Nyalam and Dingri counties of the Tethyan Himalaya in South Tibet.

The two species of *Witchellia* from unit 6 clearly indicate the Laeviuscula Zone, so that the associated Indonesian *Fontannesia* species and the entire association can now be dated as contemporary with the Western Australian *Fontannesia–Witchellia–Pseudotoites* Association (Arkell and Playford 1954). The '*D. xizangensis*' Wang (*in* Zhao 1976) from the lowest Jurassic part of the section is incompletely preserved and not identifiable, even to generic level.

Locality 3. Chana, east of Dingri, Dingri County, Tethyan Himalaya (Wang *in* Zhao 1976). Bajocian and Callovian ammonites (coll. Fd IV-19) were found here. The only Bajocian ammonite species is *F.* cf. *arabica* Arkell [or ?*W.* cf. *laeviuscula*] indicating the (?)Laeviuscula Zone. The higher fauna includes ?*Subkossmatia* sp. juv. and *Oxycerites* n. sp. A suggesting the ?Tithonian and (late) Early Callovian.

Locality 4. Ningcun, Gongdang, Gyirong County, Tethyan Himalaya. A small *Witchellia*–?*Fontannesia* fauna has recently been found here (Liu Shi-kum of Geological Bureau of Tibet, pers. comm.), suggesting the same Early Bajocian fauna as in the uppermost Lungma Limestone and lower Nichnieh Hsiungla Formation of localities 1 and 2. This fauna is not described in this report.
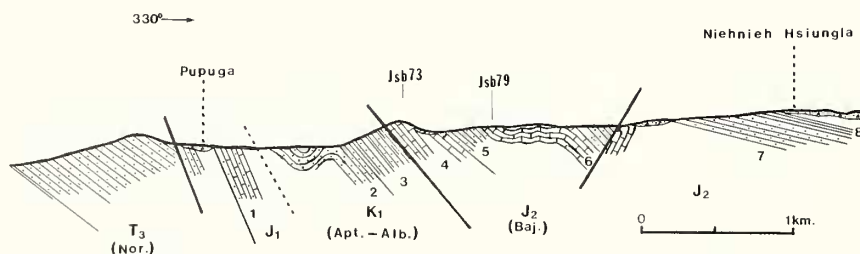
TEXT-FIG. 5. Pupuga section (loc. 2), 2 km east of Tulong, South Tibet (after Yin *et al.* 1974, revised). For unit members see text.
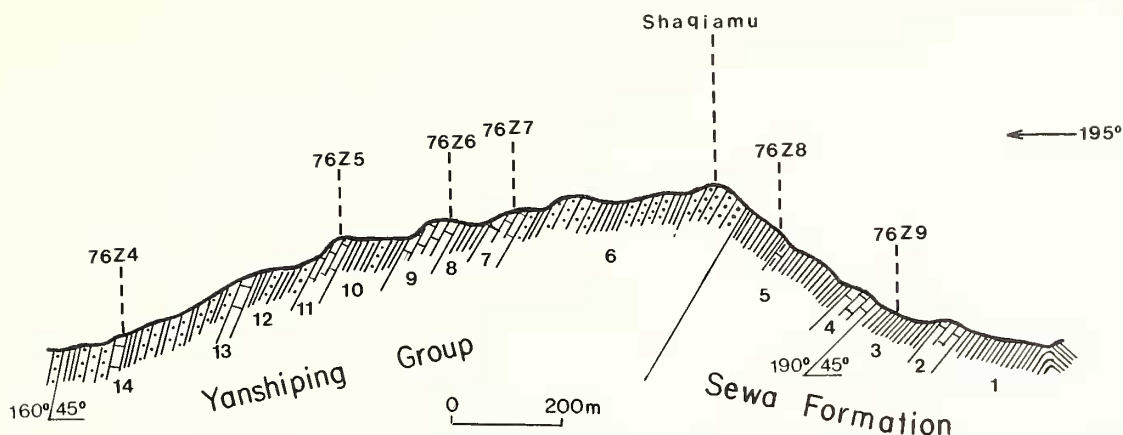
TEXT-FIG. 6. Shaqiaomu Hill section (loc. 5) at Shaquiaomu, north of Sewa, Baingoin County, North Tibet (after Wen, MS). For unit numbers see text.

Locality 5. Shaqiamu Hill of Sewa, north Baingoin County, North Tibet (Wen 1979, p. 153). This is the only evidence for marine Bajocian in the Dengquen–Shiquanhe District (text-fig. 6, after Wen, unpubl.). The Yanshiping Group (685 m) consists of sandstone, shale, and some limestone, yielding a near-shore fauna of corals, bryozoans, gastropods, bivalves, and crinoids. It cannot be dated precisely in the absence of ammonites. The subjacent Sewa Formation (590 m) is predominantly shale.

Unit 3 (coll. 76Z9) has yielded *Sonninia* sp. indet. and, somewhat higher, *D.* cf. *romani* (Oppel).

The small and poorly preserved assemblage from unit 3 establishes the Lower Bajocian, and strongly indicates the Romani Subzone of the Humphriesianum Zone.

Locality 6. 10 km north of Baquen County, North Tibet (Wang and Chen *in* Wang *et al.* 1979). One specimen of *Sonninia s.l.* sp. indet. (coll. XVIP2F-1) establishes the presence of marine Lower Bajocian at this most north-eastern Middle Jurassic marine locality in China.

Locality 7. Mali, Lhorong County, East Tibet. A few specimens of '*Macrocephalites*' (unfigured) tentatively suggest the Lower Callovian.

Locality 8. Zhaxizhong, southern bank of Panqu river, Dingri County, Tethyan Himalaya (Zhao 1976). Levels C1–2 (below) yielded *M.?* cf. *etheridgei* (Spath); levels C4–6 (above), *Grayiceras*? *waageni* (Uhlig). ?Early Callovian.

Locality 9. Pazhuo, Dingri County, Tethyan Himalaya. A single *G.?* cf. *gucuoi* n. sp. and several *G.?* aff. *waageni* (Uhlig) suggest the late Early Callovian.

Locality 10. 3–5 km south-west of Gamba, Tethyan Himalaya (Zhao 1976). Collected by Gu Qin-ke and associates (Geological Bureau of Tibet). Three assemblages are recognized, numbered from the top.

1. *Choffatia* assemblage (units Kp14 to Kp18): with *C.* cf. *balinensis* (Neumayr) and *C.* cf. *madani* (Spath). The exact stratigraphic position of both species is obscure in Kachchh, although Spath indicated that *C. balinensis* is from the '*Anceps* Beds', and *C. madani* probably from the '*Diadematus* zone'. We follow Mangold's opinion (pers. comm.) that both species are from the Late Early Callovian *Proplanulites koenigi* Zone, i.e. Calloviense/Gracilis Zone.

2. '*G.*' *gucuoi* assemblage (units Kp7 to Kp13): with *G.?* *gucuoi* n. sp. and *C.* cf. *madani*.

3. '*G.*' *waageni* assemblage (units Kp1 to Kp6). *G.?* *waageni* (Uhlig) and unidentified larger macrocephalitids.

Locality 11. Puna-Gongdasangba, about 5 km west of Zhaxizhong, Dingri County, Tethyan Himalaya (coll. JSPf 11). *Erymnoceras* n. sp. aff. *coronatum* (Brug.), *Calliphylloceras*, and *Goniomya* sp. The new species of *Erymnoceras* is close to *E. coronatum*, index of the Middle Callovian Coronatum Zone.

Locality 12. 14th–15th maintenance squads of Tibet–Qinghai Highway, north of Amdo County, North Tibet. Wang and Chen (*in* Wang *et al.* 1979) recorded '*Kellawaysites* sp.' [*Reineckeia s.l.*] and '*Dolikephalites*'
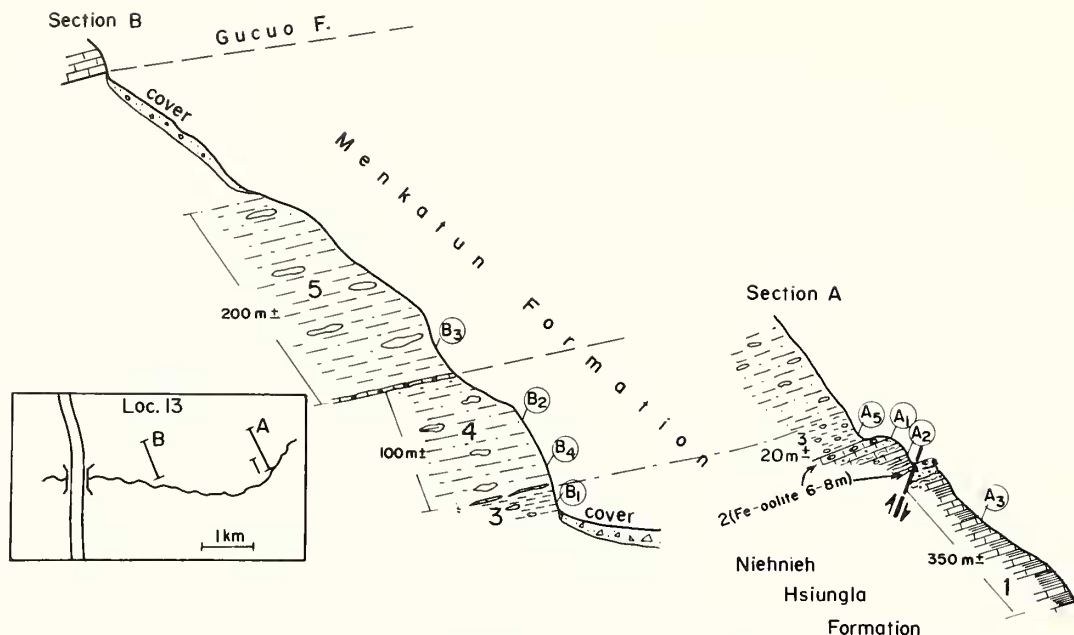
TEXT-FIG. 7. Gucuo sections (locs. 13A, B), near Lhasa–Nyalam Highway, about 25 km south-west of village of Gucuo. The Ferruginous Oolite, together with the topmost Niehnieh Hsiungla Formation, has been duplicated structurally (attitude of fault uncertain). For composite section and unit numbers see text-fig. 8. Collecting points (beds) encircled.

[Macrocephalites] from this locality (XF 590-2). The new finds of Choffatia cf. funata indicate the Calloviense Zone, whereas the reineckeid could be Middle Callovian.

Locality 13. Small valley crossing the Lhasa–Nyalam highway, approximately 25 km south-west of Gucuo, Tethyan Himalaya. Huang Xa-ping collected some Middle and Upper Jurassic ammonites from this locality which he tentatively identified as: Lytoceras sp., ?Holcophylloceras sp., diverse Macrocephalitinae, Kheraiceras cosmopolitum (Parona and Bonarelli), and 'Gymnodiscoceras sp.' (from the upper beds); diverse Macrocephalitinae, Reineckia, Hecticoceras sp., ?Subgrossouvria sp., and '?Gymnodiscoceras sp.' (from the middle beds); diverse Mayaitinae and 'Uhligites sp.' (from the lower beds). One of us (Wang) examined the illustrations, but we were unable to see the specimens, so that Huang's identification cannot be verified. Note that Mayaitinae are said to occur below Macrocephalitinae.

We examined a composite section from 1 to 4 km from the bridge on the northern slope of the valley (text-figs. 7 and 8), concentrating on the uppermost part of the Niehnieh Hsiungla Formation and the lower part of the Menkatun Formation. The Menkatun Formation is approximately 510 m thick, but the upper half is concealed.

Unit 5 consists of grey-green silty shale with some concretions and two sandstone beds at the base. We found Kossmatia sp. in bed B3, 25 m above base and Aulacosphinctoides, Gymnodiscoceras, Ptychophylloceras 70 m above the base. Lower–Middle Tithonian.

Unit 4 consists of green, mid-sandy shale and mudstone, at base probably with a poorly exposed sandstone bed, marking a paraconformity; poorly fossiliferous. Near the base (bed B4) occurs the bivalve Australobuchia spitiensis. Middle–Upper Kimmeridgian.

Unit 3 consists of black, micaceous shales with small calcareous concretions. In beds B1 and A5 we found (?)Grayiceras nepaulense, G.? waageni, G.? gucuoi, Jeanneticeras cf. anomalum, Subkossmatia cf. opis, C. cf. funata, C. (Grossouvria) propinqua, Retroceramus aff. eichwaldi and subhaasti. Uppermost Lower Callovian, S. opis Zone.
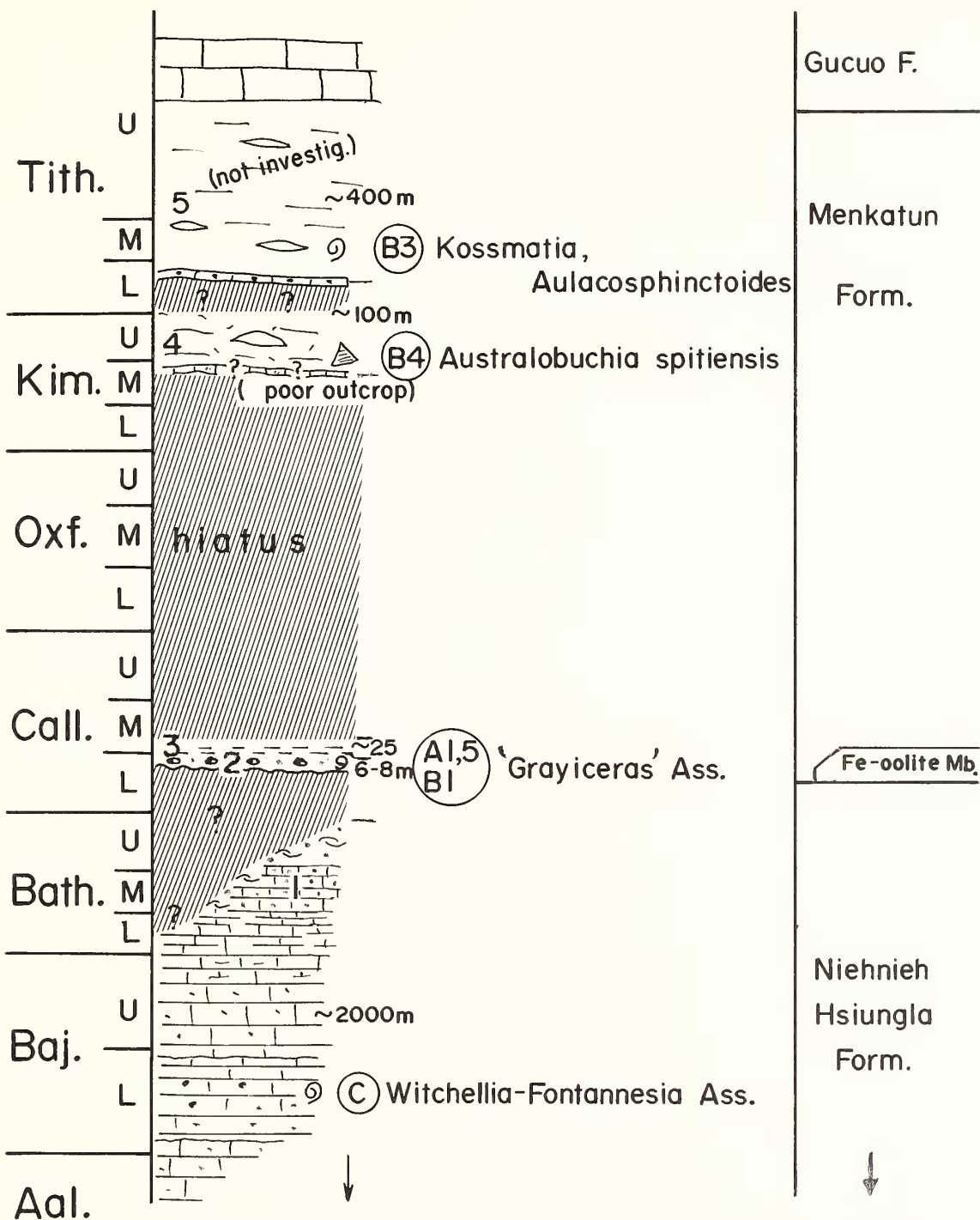
TEXT-FIG. 8. Chronostratigraphic analysis of the Gucuo composite section, with stages and substages scaled to approximate time (hence lithostratigraphy out of scale). Hiatuses, ammonite associations, and other chronostratigraphically important ammonite and bivalve occurrence indicated (circles). Same unit numbers and collecting points (beds) as in sections (text-fig. 7).
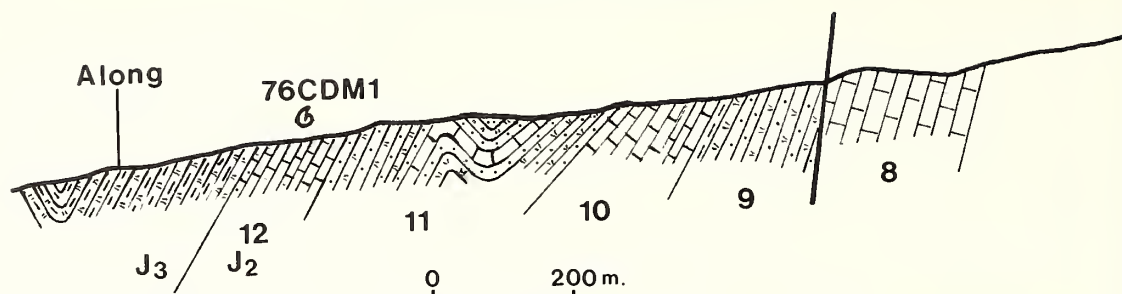
TEXT-FIG. 9. Alongge–Along section (loc. 18), Mudonga, south of Mulashan Pass, Dengqen, North Tibet. For unit numbers see text.

Unit 2, Ferruginous Oolite (Member), is an irregularly thin-bedded sideritic oolite. We found in bed A1 (?)*Grayiceras nepaulense*, *G.?* cf. and aff. *waageni*, *S.* cf. *opis. S. opis* Zone. The base is probably also a paraconformity.

Unit 1, in the topmost Niehnieh Hsiungla Formation, consists of thick-bedded bioclastic limestone interbedded with marly limestones. The bivalves *Camptonectes tibeticus*, *Astarte spitiensis*, *A. pindiroensis*, brachiopods *Septaliphoria pulchra* and *S. longjangensis*, belemnites, and crinoids were identified. Below follow more than 400 m of thin-bedded and medium-bedded limestone and marl (unfossiliferous) and about 300 m massive, quartzose sandstone (unfossiliferous).

The invertebrate assemblage of unit 1 cannot be dated with any precision. From field evidence, its stratigraphic position is more than a thousand metres above the Lower Bajocian *Witchellia–Fontannesia* Association (see locs. 1 and 2) and a gap is indicated by the contact between units 1 and 2. The probable age is therefore Bathonian to ?Lower Callovian (text-fig. 8). Unit 2 (?the Ferruginous Oolite Member as in the western Himalaya; see Jadoul *et al.* 1985) is identified as upper Lower Callovian, late Calloviense/Gracilis Zone or *Subkossmatia opis* Assemblage Zone (Kachchh) by the Mediterranean and Indo-Madagascan (Ethiopian) constituents of the '*Grayiceras*' Association. Unit 3 has the same assemblage. Significantly, the incomplete specimen of *Retroceramus* can be compared to both the Middle Jurassic *R. eichwaldi* (Kosh.) from north-east Asia and the Kimmeridgian *R. subhaasti* (Wandel) from New Zealand (S. Damborenea and J. A. Crame, pers. comm.). Unit 4 is Middle–Upper Kimmeridgian near the base according to the reliable buchiid identification made for us by J. A. Jeletzky. A paraconformity with extensive hiatus (Middle Callovian–Lower Kimmeridgian) is therefore present between the two shale units, unsuspected from the lithostratigraphy. Unit 5 is Lower? to Middle Tithonian, with the possibility of another, smaller hiatus at the base. The Menkatun Formation is clearly the lateral extension of the Spiti Shales, western Himalaya, which also has the Ferruginous Oolite 'Formation' (Member) at the base.

Locality 14. Ruxiang, Gongdang, Gyirong County, Tethyan Himalaya. *G.?* *waageni* (Uhlig) establishes late Early Callovian. This is the westernmost known Callovian occurrence in South Tibet (Yang, unpubl.).

Locality 15. Nieermei, *c.* 60 km south-east of Gyaze, Tethyan Himalaya. Recently, Liu (1983, pp. 135–136, pl. 15, figs. 3, 5–7) identified '*Macrocephalites* sp., *Indocephalites* sp. and *Gulielmiceras* sp.', all small, poorly preserved, and probably juvenile specimens. We only examined the illustrations since the specimens were not available to us. If correctly identified, the alleged Boreal (*sic*) *Kosmoceras* (*Gulielmiceras*) would indicate Middle Callovian, about Coronatum Zone. Perhaps this is a misidentified *Reineckeia s.l. Indocephalites* is now placed in *Macrocephalites*, but this could also be '*Grayiceras*'; however, all indicate the Lower Callovian.

Locality 16. Nariyong–Xiare–Zhaxikong, northern bank of Nariyong Lake, Lhunze County, Tethyan Himalaya. Wang (1985) recorded a small Callovian ammonite fauna ('*Macrocephalites* spp., *Reineckeia* sp.') from near the base of the approximately 6500 m thick Zhala Group, but the specimens were not illustrated and were lost in transit.

Locality 17. Meila near Quinghai, North Tibet (coll. F4067). *Choffatia* cf. *funata* (Oppel), collected without stratigraphic control, indicating (late) Early Callovian.

Locality 18. Alongge–Along section at Mudongga, south of Mulashan Pass, Denqen County, North Tibet (coll. 76CDM1); found in 1976 by the Tibet-Qinghai Plateau Expedition, Academia Sinica (text-fig. 9). The total thickness of the Yanshiping Group is approximately 850 m, but the lower 340 m thick massive limestone and biolithite (unit 8) is separated by a fault.

Unit 12 at the top of the Middle Jurassic (J2) section, consists of greyish white and grey, thick-bedded limestone, intercalated with greyish black argillaceous limestone, with argillaceous limestone and calcareous shale in the uppermost part; collection 76CDM1 has yielded *M.* cf. *macrocephalus* (Schloth.), *C.* cf. *funata* (Oppel), and bivalves *Entolium*, *Pteroperna*, *Anisocardia*, *Lopha*, and *Astarte*. Lower Callovian.

Unit 11 consists of brownish red, grey, green, and greyish white, medium-bedded to thick-bedded, fine feldspathic sandstone and siltstone, interbedded with argillaceous biolithite and limestone in the upper part. It has yielded the brachiopods *Burmirhynchia luchiangensis* Reed, *B. cuneata* (Ching), *B. flabilis* Ching, *B. nierongensis* Ching, *Holcothyris tangulaica* Ching, *Gervillella* cf. *siliqua* (Chang *et al.*), *Myopholas* sp., *Camptonectes* (*C.*) *rugassus* Wen, *Liostrea eduliformis* (Schlotheim), and *L. birmanica* (Reed).

Unit 10 consists of grey, thick-bedded limestone interbedded with yellowish grey biolithite. It yielded only the bivalves *L. jiangjinensis* Wen, *Camptonectes* sp., and *Meleagrinella* sp. Unit 9 consists of grey calcareous shale, grey medium-bedded to thick-bedded limestone, and feldspathic sandstone. It yielded only the bivalve *Modiolus* sp.

The ammonite fauna from unit 12 is Early or earliest Callovian, so that at least part of the subjacent brachiopod-bivalve assemblages could be pre-Callovian Middle Jurassic.

STRATIGRAPHIC CONCLUSIONS

The ages of the Middle Jurassic Tibetan ammonite assemblages (Table 1) are restricted to the Early Bajocian and Early–Middle Callovian, and here recorded in terms of the Northwest European standard zones (chronozones).

Early Bajocian

The oldest Middle Jurassic species known is *Euhoploceras* cf. *subdecoratum* of the old Hayden collection, without stratigraphic control, from our locality 1. *E. subdecoratum* occurs in Europe in the upper Concavum–Discites zones.

The Laeviuscula Zone is well documented by the widespread *Witchellia–Fontannesia* Association of localities 1, 2, and (?)4, in the Tethyan Himalaya of South Tibet. This is the former '*Witchellia–Dorsetensia* assemblage', previously believed to be the result of condensation or stratigraphically imprecise collecting, i.e. 'stratigraphic lumping' (Arkell 1953), but it appears to be a true faunal association. Note that the common *Fontannesia* specimens were formerly placed in the younger *Dorsetensia* as discussed below in the systematic part. Whereas all known species of *Witchellia* are from the Laeviuscula Zone (including Ovalis Subzone), the associated *Fontannesia* is restricted to the upper Concavum–Discites zones in Europe, but occurs abundantly in the *Pseudotoites-Witchellia–Fontannesia* fauna of the (upper) Laeviuscula Zone in Western Australia (Arkell and Playford 1954). The eastern Indonesian occurrences of *F. kiliana* remain, unfortunately, undated (Westermann and Getty 1970).

The late Early Bajocian, (?upper Sauzei–) lower Humphriesianum Zone, is strongly indicated at locality 5 in North Tibet by *D.* gr. *romani*, whereas seemingly similar Himalayan forms from South Tibet (?*D.* cf. *romanoides* of Arkell 1953) are now tentatively compared with *F.*? (n. subgen.?) *arabica* (Arkell) from the basal Bajocian of central Arabia (Enay and Mangold 1984).

Early Callovian

In North Tibet, the single large *Macrocephalites* cf. *macrocephalus* from locality 18 suggest the (?)Macrocephalus Zone, whereas the *Choffatia* cf. *funata* from localities 12, 17, 18 document the Early Callovian, possible Calloviense/Gracilis Zone. The unconfirmed '*Kellawaysites*' from locality 12 could be a Middle Callovian *Reineckeia* (*Loczyceras*) (compare Cariou 1984).

In the Tethyan Himalaya of South Tibet, the widely distributed '*Grayiceras*' Association (locs. 3, 8, 10, 13, 14) is securely dated at our locality 13. *Jeanneticeras anomalum* Elmi is from the

Ardescicum Subzone, latest Calloviense/Gracilis Zone, of France (Elmi 1967 and pers. comm.); *Subkossmatia* cf. *opis*, together with *J. anomalum*, clearly indicates the *S. opis* Assemblage Zone, uppermost Lower Callovian of Kachchh, India (Jai Krishna and Westermann 1985; Jai Krishna and Cariou 1986); *Choffatia* spp. of the *funata-balinensis-madani* group and *Oxycerites* n. sp. A (loc. 3) support the (late) Early Callovian age, whereas *C. (Grossouvria) propinqua* suggests Early–Middle Callovian.

Based on the faunas of localities 10 and 13, the '*Grayiceras*' Association can probably be divided into (*a*) a lower *G.?* *waageni* assemblage, including rare (?)*G. blanfordi* (loc. 13); and (*b*) an upper *G.? gucuoi* assemblage, including abundant *Choffatia* spp. which also range higher. Rare *S.* cf. *opis* occurs in both assemblages, whereas the single *J.* cf. *anomalum* was found in the upper assemblage (loc. 13). *G.? waageni* may range upward into the *G.? gucuoi* assemblage, but our collection at locality 13 was not accurate enough within the few metres of fossiliferous shales in unit 3 to determine the ranges precisely. The two species appear to have non-overlapping ranges at locality 10. The '*Grayiceras*' Association may be underlain by *Macrocephalites*-bearing beds at locality 8.

The alleged '*Kepplerites (Gulielmiceras)*' (Liu 1983) recorded from locality 15 in the Tethyan Himalaya, would indicate the same early Callovian age. It is more probable, however, that these Boreal taxa have been misidentified; they could possibly belong to the Tethyan *Cadomites*, recently found in southern Germany as high as the basal Callovian (Dietl 1986). The '*Kellawaysites*' from locality 12 (Wang *et al.* 1979) in North Tibet is an Early Callovian *Choffatia (Indosphinctes)* sp.

Middle Callovian

Only the several specimens of *Erymnoceras* n. sp. aff. *coronatum* of locality 11 in South Tibet establish the Middle Callovian, ?Coronatum Zone.

THE LOWER SPITI SHALES

The *Belemnopsis gerardi* Beds, or Lower Spiti Shales, of the western Himalaya have recently been reviewed by Jai Krishna and Singh (1982) who described them to be devoid of ammonites. Uhlig (1903–1910) appears to be the last author to describe and illustrate their ammonite fauna which was collected with little or no stratigraphic control at a few localities in the wider Niti-Spiti area. Uhlig's (1910*b*, 1911) extensive discussion of the collecting records, however, strongly indicates that all species named by him are from the *B. gerardi* Beds or basal Spiti Shales, just above the Ferruginous Oolite. This fauna is revised here as follows:

Uhlig (1903–1910)	This account
Macrocephalites waageni Uhlig	*Grayiceras*? *waageni* (Uhlig)
M. kitcheni Uhlig	*G.?* *waageni* (Uhlig)
Simbirskites nepaulensis	*G. nepaulensis* (Gray) ['*G. blanfordi*' Spath]
S. koeneni Uhlig	'*Idiocycloceras?/Subkossmatia? koeneni*' (Uhlig), *nomen dubium*
Perisphinctes (Grossouvria) propinquus Uhlig	*Choffatia (Grossouvria) propinqua* (Uhlig)
Oppelia (Oecotraustes) adela Uhlig	?*Puttealiceras* sp.

This fauna, except for '*S. koeneni*', and '*O. adela*', occurs together in units 2 and 3 of our locality 13, in association with *Choffatia* spp. and *C. (Indosphinctes)* sp. Our unit 2 is in the facies and stratigraphic position of the Ferruginous Oolite of the western Himalaya, which has been said to have a condensed Callovian fauna (Arkell 1956; Jadoul *et al.* 1985), whereas the superposed shales and fauna have been placed in the Oxfordian (Jai Krishna and Singh 1982) (text-fig. 10). In the Zanskar area near the north-western end of the Spiti Shales outcrop, where the only examination of the Ferruginous Oolite has been made (Jadoul *et al.* 1985), this rock body is said to be highly diachronous (but see page 295). Middle Upper Callovian is recorded only from the westernmost
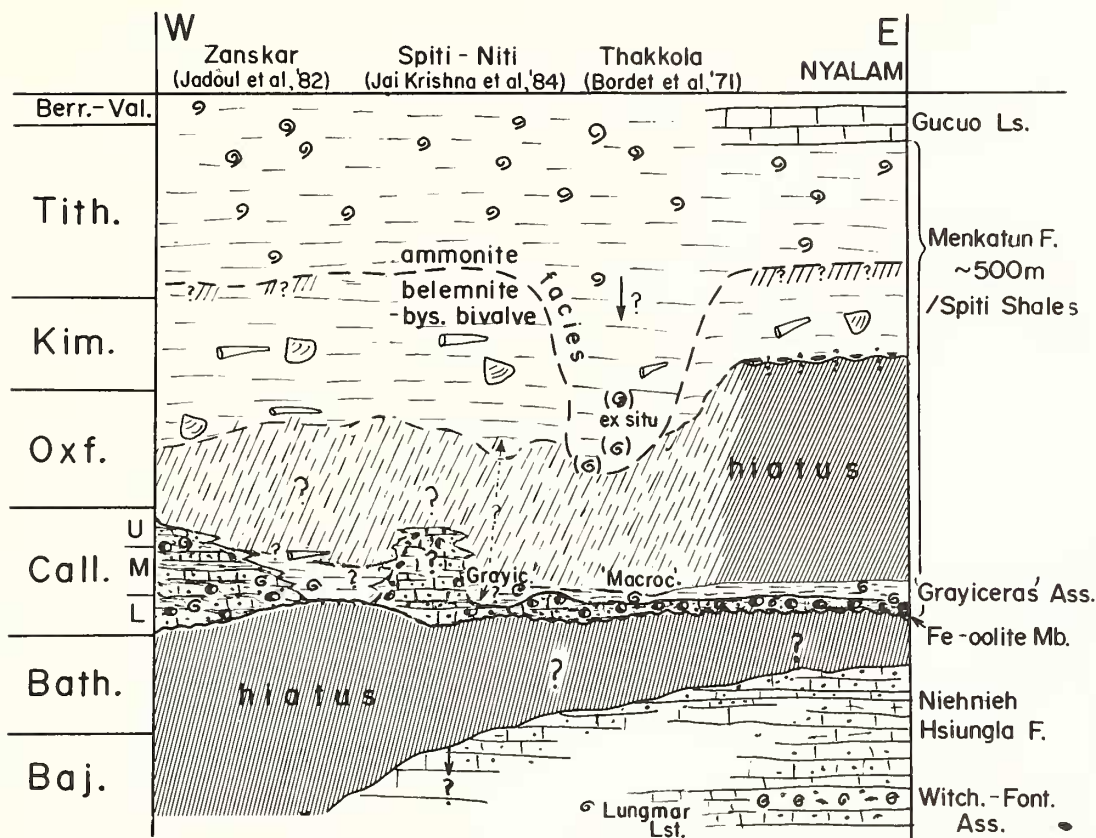
TEXT-FIG. 10. Tentative regional analysis of the Spiti Shales and equivalent Menkatun Formation, from north-eastern Pakistan to central South Tibet. Vertical chronostratigraphic scale approximating time. Hiati, lithofacies, ammonite and belemnite/byssate bivalve biofacies, and ammonite associations indicated. Note the strongly diachronous Feruginous Oolite Member and lateral shaly equivalents at the base of the Spiti Shales/Mancatun Formation, followed at least in Nyalam County by a large hiatus (but see page 295).

section at Ringdom Gomppa, whereas eastward toward Spiti, only Lower or Middle Callovian is indicated by the fauna, and the reduced easternmost sections at Tantak cannot be dated. Arkell's review of the famous Niti area (1956, p. 408) is based on records in previous literature only, with the Upper Callovian based entirely on an unconfirmed record of '*Distichoceras* cf. *bicostatum*'. We suggest that this genus could have been mistaken for an Early (or ?Middle) Callovian *Jeanneticeras* or *Chanasia*. Even if Upper Callovian should be present locally in the Ferruginous Oolite, this diachronous nearshore deposit in no way precludes the presence of any part of the Callovian in the offshore shaly facies within a few kilometres.

It is noteworthy that no clearly Oxfordian ammonite fauna is known from the western Himalaya; that even Kimmeridgian ammonite records are very meagre and doubtful; and that *Belemnopsis* is long-ranging. The correlation of the *B. gerardi* Beds with the supposedly Late Oxfordian beds that bear *Belemnopsis* and inoceramids in the Moluccas, Indonesia, has two problems: (1) The belemnite/byssate bivalve-bearing sequence, without ammonites, is a biofacies (yet unexplained) which in the Moluccas is developed in the Kimmeridgian, above Oxfordian *Epimayaites* (although single inoceramids occur also in the ammonoids facies). (2) *B. gerardi* (Oppel) is poorly known (perhaps *nomen dubium*), but the forms described by Uhlig (1910a) are related to latest Oxfordian

through Tithonian species (Challinor and Skwarko 1982). But superficially similar, large *Belemnopsis* occur in Indonesia from the Bathonian upward ('Callovian' of Challinor and Skwarko, 1982; associated ammonite faunas now re-dated, unpublished). (3) Similarly, the broad, coarsely rugose inoceramids mentioned by Uhlig (1910*b*, 1911) could be latest Oxfordian–Kimmeridgian *Retroceramus* as in eastern Indonesia and New Zealand, but *Retroceramus* occurs with similar forms, i.e. *R. eichwaldi* (Koschelkina), already in the Bajocian–Callovian of the Northern Hemisphere and, together with the Indonesian 'Oxfordian' *R.* cf. *galoi* (Boehm), in the Callovian of the Andes (J. A. Crame, pers. comm.).

Between the Niti valley and our locality 13, in the Thakkola area of central Nepal in the central Himalaya, Mouterde (*in* Bordet *et al.* 1971) has recorded ferruginous oolites and marls at the base of the Spiti Shales, yielding '*Indocephalites* gr. *urbanus, Macrocephalites* sp., and large *Oxycerites* sp.' Only the last species was illustrated and it strongly resembles our *Oxycerites* n. sp. A. This is perhaps our '*Grayiceras*' Association. Directly above are said to follow '*Epimayaites* and *Prograyiceras* of the Upper Oxfordian', but these could also be '*Grayiceras*'. From the shaly facies of this same area Mouterde gave the first reliable record of Oxfordian ammonites (found loose) in the Himalaya, i.e. *Peltoceratoides* sp. of the Lower Oxfordian and *Perisphinctes* (*Kranaosphinctes*) *indogermanus* Waagen, *P.* (*Arisphinctes*) gr. *hellenae* De Riaz, and *P.* (*Orthosphinctes*) sp. of the Upper Oxfordian, together with what appear to be true mayaitids.

We suggest that the pre-Kimmeridgian hiatus documented for our locality 13 in the central Himalaya of Tibet may extend to other areas, with the higher Callovian and Oxfordian frequently missing (Bossoullet *et al.* 1977). Extensive stratigraphically controlled collecting will have to be done in the Lower Spiti Shales, however, before hiatuses can be distinguished from the regional absence of ammonoid biofacies (the *Belemnopsis*—byssate bivalve biofacies cannot be dated accurately), and before the age of the Lower Spiti Shales/*Belemnites gerardi* Beds can be clearly determined.

BIOGEOGRAPHIC CONCLUSIONS

According to the plate-tectonic subdivision of Tibet (text-figs. 2 and 3) the Middle Jurassic ammonite localities (locs. 5, 6, 12, 17, 18) belong to (*a*) the North Tibetan Qamdo block or terrane which since Early Jurassic was amalgamated with Eurasia; (*b*) the north-eastern margin of the South Tibetan/Lhasa block or terrane (loc. 7) which was still separated from Eurasia (including North Tibet) by the narrow Tanggula Ocean; and (*c*) the Tethyan Himalaya area (locs. 1–4, 8–11, 13–16) at or near the northern margin of the Indian Shield, then part of Gondwana at the south shore of Tethys. We will consider whether the fossil record supports the 'mobilistic' hypothesis. The samples from the first two areas are, unfortunately, small and poorly preserved, or small and not available to us for examination. The affinities of Himalayan ammonite species to other ammonite provinces have been listed in Table 2, including the northern and western Australasian area of extreme south-eastern Tethys (eastern Indonesia and Western Australia). In the table, definite species identifications are given the score of 1, uncertain identification 0·5.

Bajocian

The poorly known ammonite fauna from North Tibet includes *Dorsetensia* cf. *romani*, a species of mainly European, but also Andean and possibly East African distribution (Westermann 1975).

The ammonite fauna from the Tethyan Himalaya of Tibet is mainly endemic (score = 2, see Table 2). Its closest affinity is to eastern Indonesia, i.e. the Sula Islands and Irian Jaya (1·5), whereas the pan-Tethyan to cosmopolitan, Indo-East African–Madagascan (Ethiopian) and West-Tethyan elements are minor (0·5 each). The scarcity of Ethiopian elements, however, is probably misleading, because coeval marine fauna is represented by only a few specimens from Madagascar (Collignon 1958, figs. 28–30) and Kenya (Westermann 1975, pl. 2, figs. 1 and 3). Current work by one of us (G. E. G. W.) in Kenya indicates indeed that *Grayiceras*-like ammonites are present

TABLE 2. Biogeographic Analysis of Himalayan Fauna from Tibet.

Species	Pan-Tethyan	West-Tethyan	Ethiopian	E. Indon. + W. Austr.	Endemic
Bajocian					
Euhoploceras cf. *subdecorata*	(+)				
Witchellia cf. *australica*				(+)	
W. tibetica					+
W. cf. *sutneri*		(+)	(+)		
Fontannesia haydeni					+
F. kiliana				+	
Subtotal	0·5	0·5	0·5+	1·5	2
Callovian					
Jeanneticeras cf. *anomalum*		(+)		+	
Grayiceras blanfordi					+
G. ?*waageni*					+
G. ?*gucuoi*			?		(+)
Subkossmatia cf. *opis*			+		
Erymnoceras aff. *coronatum*					+
Choffatia cf. *madani*	(?)		(+)		
C. cf. *balinensis*	(+)				
C. cf. *funata*	(+)	(+)			
C. (*Grossouvria*) *propinqua*					+
Subtotal	1	1	1·5 +	1	4·5
Total score	1·5	1·5	2·5	2·5	6·5

(Uncertain identifications placed in parenthesis and scored half unless genus restricted similarly.)

there in the middle part of the Callovian. In addition, some Arabian affinity is suggested by *F*.? cf. and aff. *arabica*.

Callovian

The ammonite fauna of North Tibet is known only from a large incomplete *Macrocephalites* cf. *macrocephalus* of typically European appearance, and from the cosmopolitan *Choffatia* spp.

The analysis of the ammonite fauna of the Tethyan Himalaya of South Tibet is also provisional. Endemism appears to be high (score = 4·5), with the affinities of the remaining elements being probably stronger to India–East Africa–Madagascar than to pan-Tethys, West-Tethys, and eastern Indonesia. Reports of single Boreal elements from South Tibet were presumably based on misidentifications. As in the case of the Bajocian fauna, however, resemblances to the Ethiopian and eastern Indonesian faunas may be underrated due to differences in biofacies and incomplete stratigraphic records.

In conclusion, the affinities of the Middle Jurassic ammonite species from the Tethyan Himalaya

of Tibet support the 'mobilistic' (plate-tectonic) model, i.e. that their habitat was at the southern margin of Tethys, with connections to western India, East Africa, and Madagascar, as well as north-western Australasia. The limited evidence from North Tibet, on the other hand, is consistent with a Eurasian position.

The latest Jurassic (Tithonian) ammonoid affinities of the Tethyan Himalaya become extremely close to north-western Australia which consequently Uhlig (1911) correctly included in the Himalayan Province. The Tethyan Himalaya, thus, lay at the junction (ecotone) of the north–south extending Ethiopian and the west–east trending Himalayan ammonoid provinces (or subprovinces of Indo-East Africa Province of Jai Krishna 1983).

SYSTEMATIC PALAEONTOLOGY

The specimens referred to below were deposited in the following institutions: NIGP, Nanjing Institute of Geology and Paleontology, Academia Sinica, Nanjing; A, Geological Bureau of Xizang, Lhasa; K, Geological Survey of India, Calcutta; and J, Department of Geology, McMaster University, Hamilton, Ontario.

Family SONNINIDAE Buckman, 1892

Our material from Tibet contains four genera: *Sonninia*, *Euhoploceras*, *Witchellia*, and *Dorsetensia*. There are close similarities between *Witchellia* and *Dorsetensia* on the one hand, and *Sonninia* and *Euhoploceras* on the other (Westermann 1969; Huf 1968; Westermann and Riccardi 1972; Morton 1972; Donovan *et al.* 1981). *Euhoploceras* has only recently been separated from *Sonninia* while *Witchellia* and *Dorsetensia* have long been recognized as genera. Intermediate forms between the genera exist, however, and are difficult to classify. Note that close affinities also exist between *Dorsetensia* and *Fontannesia* which is now placed in the Hildoceratidae (Westermann and Getty 1970). This suggests that *Witchellia* and *Dorsetensia* may also find a better place among the Hildoceratidae than among the Sonniniidae.

Genus SONNINIA Bayle, 1879
Sonninia s.l. sp.

 v 1979   *Cyclicoceras* sp.; Wang and Chen *in* Wang *et al.*, p. 58, pl. 17, fig. 9.

Material. The poorly preserved NIGP 34074 from loc. 6.

Description. The specimen is of medium size, somewhat involute, with a rather high keel. The flexed ribs generally bifurcate at mid-flank in small nodes, form a series of blunt nodes on the umbilical shoulder, and project on the ventral shoulder.

Remarks. This specimen is undoubtedly a typical *Sonninia*, but the poor preservation prevents specific identification.

Genus EUHOPLOCERAS Buckman, 1913

The 'genotype' of '*Sherbornites*' (Buckman 1923, pl. 411) is intermediate between *Euhoploceras* and *Papilliceras*, with a spinous stage on the inner whorls as in the former and a series of lateral tubercules on the body-chamber as in the latter. Its geographic distribution is cosmopolitan.

Euhoploceras cf. *subdecoratum* Buckman, 1893 (♂?)

 1953   *Sonninia* aff. *dominans* Buckman; Arkell, p. 322, pl. 14, fig. 8*a*, *b*.

Material. Arkell's (1953) description of the small and entirely septate specimen (K9/247) from our loc. 1.

Description. The evolute shell has an oval whorl-section and a well-developed spinous stage to approximately 40 mm diameter. One flank of the last half-whorl has approximately twenty ribs.

Discussion. The specimen is very close to *Sonninia subdecorata* Buckman (1893, pl. 84, figs. 9–11) except for the somewhat more distant ribbing. Westermann tentatively considers *E. subdecoratum* to be the microconch of *Euhoploceras adicra*.

Age and distribution. *E. subdecorata* and related macroconchs mark the Aalenian–Bajocian boundary beds of Europe.

Genus WITCHELLIA Buckman, 1889

Although the generic names *Witchellia* and *Dorsetensia* were established in the last century, problems of matching the macroconchs with the microconchs remain, i.e. the correspondence between *Witchellia* ♀ and *Pelekodites* ♂, and whether '*Zugophorites*' is synonymous with *Witchellia*, and '*Hyalinites*' with *Witchellia* or *Dorsetensia*.

Witchellia cf. *australica* Arkell, 1954

1953   *Witchellia* aff. *platymorpha* Buckman; Arkell, p. 333, pl. 14, fig. 6*a*, *b*.
* ? 1954   *Witchellia australica* Arkell *in* Arkell and Playford, pp. 561–563, 584–585, figs. 4 and 9.

Material. Arkell's (1953) description of specimens K9/231, 248, and possibly also 235 from our loc. 1; one fragmentary large septate specimen J2186 from loc. 2.

Remarks. This form was originally compared with *W. platymorpha* Buckman on the basis of 'wide, distant, feeble ribbing lost early and a high flat-sided whorl with tabulate, strong tricarinate venter' (Arkell 1953). Whereas both forms undoubtedly belong to the involute *W. laeviscula* group (Westermann 1969), the Tibetan form is more weakly ribbed becoming smooth on the mature flanks.

Arkell (*in* Arkell and Playford 1954) compared one Tibetan specimen (K9/231) with *W. australica* Arkell. Although the Tibetan specimens resemble the holotype in the gradual umbilical slope and rounded shoulder, they differ in the 'broad tabulate venter bearing a large but blunt medial keel flanked by grooves' and 'faint ribbing of the nucleus, and thereafter the whorls are smooth or carry only faint indefinite falcoid fold'. Specimen K9/248 is also similar to the holotype of *W. australica* in venter and ornamentation, but has a rather steep umbilical wall and a subangular umbilical shoulder.

Age and distribution. *W. australica* is known from the Laeviuscula Zone of Western Australia.

Witchellia tibetica Arkell, 1953

1953   *Witchellia tibetica* Arkell, p. 332, pl. 14, fig. 7*a*, *b*. [holotype].

Material. Arkell's (1953) descriptions of specimens K9/245 and 240 from our loc. 1.

Remarks. This species was established on the basis of the holotype (K9/245) and one questionable specimen (240) only. Arkell considered *W. glauca* Buckman as the nearest European species, with *W. tibetica* being more evolute and more finely ribbed. Westermann (1969) suggested that *W.* '*glauca*', *W.* '*actinophora*', and *W.* '*falcata*' Buckman are synonymous with *W. sutneri* (Branco); but all have falcate ribs with bullae-like primaries, which *W. tibetica* lacks. *W. tibetica* appears to be closest to the European morphospecies '*Zugophorites*' *zugophorus*, '*Gelasinites*' *gelasinus* Buckman from the lower Laeviuscula Zone, and *W. sayni* (Haug), as is evident in the rather evolute coiling, the strong, dense ribs, the tricarinate–bisulcate venter, the steep and low umbilical wall, and the subangular umbilical margin. However, we could not re-examine the Tibetan specimens which are deposited in the Geological Survey of India.

Distribution. Possibly endemic to Tibet.

Witchellia cf. *sutneri* (Branco, 1879)

Plate 20, figs. 8–9

v 1976   *Witchellia tibetica* Arkell; Wang *in* Zhao, p. 517, pl. 3, figs. 9–12 [*non* Arkell, 1953].
v 1985   *Witchellia tibetica* Arkell; Wang, pl. 1, fig. 7.

Material. Septate NIGP 30420 and 30421 from loc. 2 (coll. Jsb79).

Remarks. Both specimens undoubtedly belong to *Witchellia* on the basis of the falcate ribs and bisulcate venter. They are morphologically between *W. sutneri*, with evolute coiling, and *W. tibetica* Arkell, with dense ribs and lacking bullae-like primaries, but more similar to the former. The septal suture on NIGP 30421 has a wide E lobe with low median saddle, a wide E/L saddle divided by a small incision, and smaller and narrow L and U lobes. *W. glauka* Buckman and *W. falcata* Buckman from the English Laeviuscula Zone are closely affiliated or conspecific.

Age and distribution. *W. sutneri* occurs in the Laeviuscula Zone of north-west Europe.

Family SONNINIIDAE or HILDOCERATIDAE
Genus DORSETENSIA Buckman, 1922
Dorsetensia cf. *romani* (Oppel, 1857) ♀

Plate 20, figs. 10–11

v ? 1976   *Dorsetensia xizangensis* Wang *in* Zhao, p. 519, pl. 4, figs. 17 and 18.

Material. NIGP 84768 and possibly also 84765 from loc. 5 (coll. 76Z9) in North Tibet.

Remarks. The fragmentary macroconch NIGP 84768 (d $\simeq$ 113 mm) closely resembles the holotype of *D. romani* which was refigured by Huf (1968, pl. 13, fig. 6*a–e*). The flanks of the body-chamber are flat and converge toward the fastigate, sharp venter, and some irregular, feeble, slightly flexed folds can be observed on its medial and inner flanks. The umbilical wall is steep with subangular margin.

   D. xizangensis Wang is also similar, but it is based on an incomplete, undiagnostic specimen and is here considered a *nomen dubium*.

Age and distribution. *D. romani* occurs in Europe and the Andes of Chile (Westermann and Riccardi 1972). It is the index of the Romani Subzone, Humphriesianum Zone.

Family HILDOCERATIDAE Hyatt, 1867
Subfamily GRAMMOCERATINAE Buckman, 1905
Genus FONTANNESIA Buckman, 1902

We follow Westermann and Getty (1970, p. 240) in transferring the genus from the Sonniniidae to the Grammoceratinae.

EXPLANATION OF PLATE 20

Figs. 1–4, 6, 7. *Fontannesia kiliani* (Kruizinga), from loc. 2 (coll. Jsb 79), × 1.   1 and 2, (♀), NIGP 30426.
   3 and 4, (♀), NIGP 30427.   6 and 7, (♂), NIGP 30429.
Fig. 5. *Oxycerites* n. sp. A, (♂), NIGP 84763 (coll. FdIV-11), loc. 3, × 1.
Figs. 8 and 9. *Witchellia* cf. *sutneri* (Branco), (♂), NIGP 30421 (coll. Jsb 79), loc. 2, × 1.
Figs. 10 and 11. *Dorsetensia* cf. *romani* (Oppel), (♀), NIGP 84768 (coll. 7639), loc. 5, × 0·5.
Figs. 12–14. *F.*? cf. *arabica* Arkell, (♀), NIGP 30423 (coll. FdIV-19), loc. 3, × 0·6.

PLATE 20
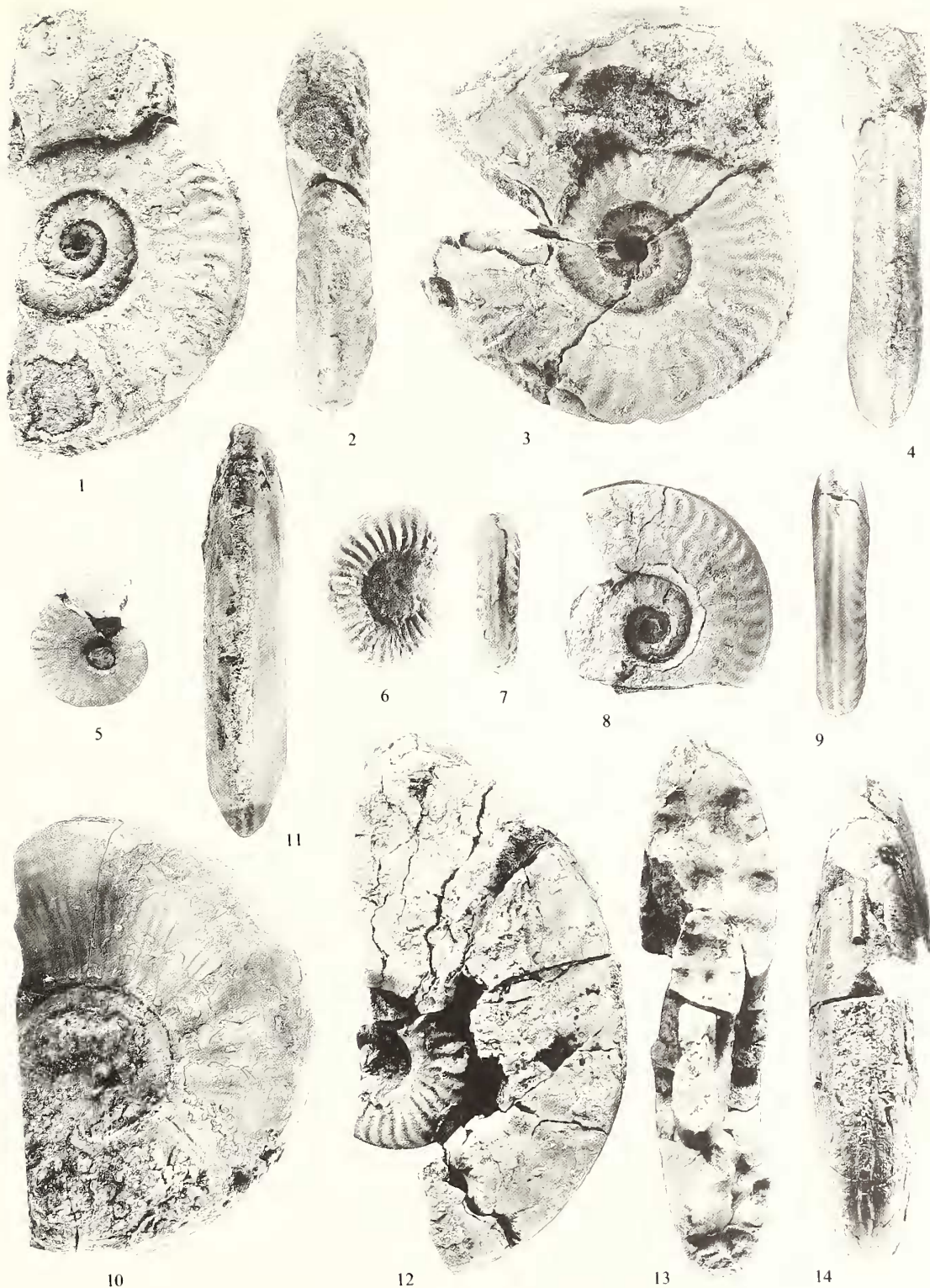
Fontannesia haydeni (Arkell, 1953)

* 1953   *Dorsetensia haydeni* Arkell, p. 334, pl. 13, fig. 5*a–c*; pl. 14, fig. 9*a*, *b*.
non v 1976   *Dorsetensia haydeni* Arkell; Wang *in* Zhao, p. 518, pl. 4, figs. 12–16.
non v 1985   *Dorsetensia haydeni* Arkell; Wang, pl. 1, figs. 9 and 10.

Material. Arkell's (1953) description of specimens K9/246, 239, and 244 from loc. 1.

Description. This is an evolute, rather compressed, medium-sized form with a subovate whorl-section and a blunt keel on the narrow-rounded venter. The slightly flexed and dense ribs are restricted to the inner whorls and gradually weaken outward to become irregular and obsolete. The umbilicus is large with gentle slope.

Discussion. Arkell (1953 and 1954 *in* Arkell and Playford) pointed out that this form comes close to the Australian '*D.*' *clarkei* Crick and the very similar '*D.*' *whitehousei* Arkell which he correctly believed should probably be transferred to *Fontannesia*. The Tibetan specimens resemble *F. clarkei* var. *whitehousei* but are even weaker in ornamentation, probably beyond the range of variability of *F. clarkei*. We thus retain the species *F. haydeni* for the time being.

Age and distribution. Whereas *F. haydeni* appears to be endemic to Tibet, the closest relative, *F. clarkei*, occurs in the Laeviuscula Zone of Australia.

Fontannesia kiliani (Kruizinga, 1926) ♀ (and ♂)

Plate 20, figs. 1–4, 6–7

v * 1926   *Grammoceras Kiliani* Kruizinga, p. 38, pl. 7, fig. 2 [♀].
  ? 1953   *Dorsetensia* cf. *regrediens* (Haug); Arkell, p. 13, pl. 13, figs. 2*a*, *b*, 3 [♂].
  v   1970   *Fontannesia* aff. *F. clarkei* (Crick) ?subsp. *kiliani*; Westermann and Getty, p. 238, pl. 48, figs. 1–4; pl. 49, figs. 1–4, text-figs. 4 and 5 part [♂].
  v   1976   *Dorsetensia* cf. *edouardiana* (d'Orbigny); Wang *in* Zhao, p. 518, pl. 4, figs. 10 and 11 [♂].
  v   1976   *Witchellia sayni* Haug; Wang *in* Zhao, p. 518, pl. 3, figs. 4–6.
      1985   *Dorsetensia haydeni* Arkell; Wang, pl. 1, figs. 9 and 10.

Material. NIGP 30425–30427, 30428, 30429, ?30422, and J2187 from loc. 2; Arkell's (1953) microconchs K9/232, 243 from our loc. 1.

Description. The macroconch is of medium size (60–90 mm), moderately evolute, and strongly compressed with tabulate, keeled venter of medium height. It bears slightly flexed and moderately projected simple ribs on middle and outer flanks which become blunt, rarely obscure, on the outermost whorl. The umbilical slope of the inner whorls is shallow or absent, but becomes steep and subangular on the outermost whorl. The microconch is only 30 to 40 mm large, with evolute and slightly compressed whorls, narrowly tabulate venter with blunt rounded keel, and prominent simple ribs over the entire flanks. The ribs are slightly sinuous and projected on the ventral shoulder, as in the macroconch.

Discussion. There is good resemblance to the European *D. deltafalcata* (Quenstedt) in macroconchs and microconchs (cf. Huf 1968, pl. 9, fig. 6*a–c* for microconch, pl. 10, figs. 2*a–c*, 3*a–c* for macroconchs). This Tibetan form was, in fact, identified by us with that species of the Humphriesianum Zone before being found in association with *Witchellia* indicating the Laeviuscula Zone. The perfect match of the macroconch is, however, with *F. kiliani* from the Moluccas and Irian Jaya, Indonesia, as illustrated by the holotype and better, new material by Westermann and Getty (1970). The smoother inner flank with gentle slope of the inner whorls distinguish it from *Dorsetensia*. The West Australian *F. clarkei* (Crick) and its several, probably synonymous, close allies from the Laeviuscula Zone (Arkell and Playford 1954) differ in the more rounded whorls, with less developed umbilical shoulder and ventral tabulation particularly in the adult, and in the

widely spaced costae becoming obsolete. Significantly, the other probable *Fontannesia* from the Moluccas, *F. baumbergeri* (Kruizinga), closely resembles *F. clarkei*.

Age and distribution. Moluccas and Irian Jaya, Indonesia, undated (found loose).

Fontannesia? (n. subgen.?) cf. *arabica* Arkell, 1952 ♀

Plate 20, figs. 12–14

v 1976   *Witchellia laeviusculus* (Sowerby); Wang *in* Zhao, p. 517, pl. 3, figs. 15 and 16.

Material. NIGP 30423 and 84779 from loc. 3.

Description. The better preserved fragment NIGP 30423 is about 122 mm in diameter and entirely septate. The inner whorls of both specimens have eighteen to twenty simple ribs per half-whorl. The outer whorl has only very weak folds on the inner and medial flanks and a rounded, floored keel on the subtabulate venter. The septal suture is very simple and with wide E/L saddle.

Discussion. Whereas our specimens resemble somewhat the European and Andean macroconchs of *Dorsetensia*, e.g. *D. liostraca* forma *subtecta* Buckman (1892), the closest resemblance is to the earlier central Arabian '*D.*' *arabica* (Arkell 1952) in their simple immature ribs. Although there is close superficial resemblance to *W. laeviuscula* (Sow.), the simplified septal suture, the probably floored keel without ventral sulci, and the regular simple ribs militate against assigning the specimens to *Witchellia*. Additional material and associated fauna is needed to solve the problems of generic taxonomy. We suggest that this could be a *Dorsetensia* homoeomorph affiliated to *Fontannesia* with which it is contemporaneous, and it may be classified as a new subgenus of *Fontannesia*.

Age and distribution. '*D.*' *arabica* has recently been dated as basal Bajocian in central Arabia (Enay and Mangold 1984).

Fontannesia? n. sp. aff. *arabica* ♂

1953   *Dorsetensia* cf. *romanoides* (Douvillé); Arkell, p. 333, pl. 13, fig. 1*a*, *b*.

Material. Arkell's (1953) description of specimen K9/237 from our loc. 1.

Remarks. Arkell (1953) noted this macroconch resembles *D. pulchra* Buckman, except for the more inflated whorl section (H/W = 1·65 from illustration) which resembles that of *D. romanoides*. However, both *D. pulchra* and *D. romanoides* are strongly compressed and more bluntly ribbed than the Tibetan form and believed by Huf (1968, pp. 86–87) to be conspecific with *D. romani* (Oppel). Westermann and Riccardi (1972, p. 98) noted that the Tibetan macroconch closely resembles the European *D. edouardiana* and probably also '*D.*' *arabica* Arkell. The possibility exists, however, that this form is an unusual *Fontannesia* macroconch, particularly since the (?associated) microconch described by Arkell (1953) under *D.* cf. *regrediens* belongs indeed to *F.* gr. *kiliana* and '*D.*' *arabica* is earliest Bajocian (see below). Arkell's (1953) *D.* cf. *romanoides* came from the Lungmar Limestone and was found together with species of the Discites–Laeviuscula zones. This unnamed species differs from *F.?* *arabica*, probably its closest ally, in the larger diameter and more involute and compressed-lanceolate whorls.

Family OPPELIIDAE Douvillé, 1890
Subfamily OPPELIINAE Douvillé, 1890
Genus OXYCERITES Rollier, 1909
Oxycerites n. sp. A. ♂

Plate 20, fig. 5

Material. A small septate specimen NIGP 84763 from loc. 3 (FdIV-11).

TEXT-FIG. 11. Lateral and apertural views of *Jeanneticeras* cf. *anomalum* Elmi, ♂, J2189. Complete microconch from '*Grayiceras*' Association, bed A5 of loc. 13, × 1.

Description. The phragmocone (20 mm diameter) appears to be adult. It is moderately involute with sharp ventrolateral ribs on the last half-whorl and probably a microconch. The flanks are a little convex and converge gradually towards the acutely fastigate venter (h ≃ 10 mm, b ≃ 5·5 mm). The inner whorls are entirely smooth; broad, short ribs start to appear on the outer flank and ventral shoulder only on the last septate whorl (Wh > 3·9 mm) whereas the inner half of the flank remains smooth. The ribs widen towards the venter where they project sharply and die out close to the fastigation. The umbilicus slopes gently and is rather small (3·7 mm).

Discussion. The specimen is very close to '*Oppelia fusca*' of Boehm (1912, p. 143, pl. 33, fig. 3a–3; pl. 34, figs. 1a, b, 2, 3) from the upper Lower Callovian of Indonesia. That form is currently being classified as a new species of *Oxycerites* (Westermann and Callomon, unpubl.) based mainly on the ribbing which changes gradually from dense to widely spaced, and the acutely fastigate venter.

Age and distribution. The closest ally occurs in the Calloviense/Gracilis Zone of the Moluccas, Indonesia.

<div style="text-align:center">

Subfamily HECTICOCERATINAE Hyatt, 1900
Genus JEANNETICERAS Zeiss, 1956

</div>

Elmi (1967) raised the original subgenus to the genus level and discussed the taxonomy and distribution of *Jeanneticeras* in detail. The genus has been known only from the Lower Callovian of the Mediterranean and Submediterranean provinces. This 'microconch genus' appears to correspond to several hecticoceratid genera in their restricted sense (Elmi 1967).

<div style="text-align:center">

Jeanneticeras cf. *anomalum* Elmi, 1967 ♂

Text-fig. 11a, b

</div>

cf. 1967   *Jeanneticeras anomalum* Elmi, p. 763, pl. 16, figs. 1–3, 5; text-figs. 184, 195, 196.

Material. One complete microconch J2189 from bed A5, loc. 13.

Description. The complete microconch is 45 mm in diameter. The septate whorls are involute and compressed trapezoidal, with broadly rounded venter. Their ornamentation consists of subradial primaries and dense, projected secondaries which terminate on the ventrolateral shoulder in small tubercles. The septal suture is moderately incised; approximation at the end of the phragmocone indicates maturity. The body-chamber is slightly less than a half-whorl long, agresses strongly at the umbilical seam, and terminates in partially preserved lateral lappets. The costae become increasingly falcate and blunt on the lower and middle flanks; the secondaries become much more widely spaced, and the terminal tubercles elongate into well-developed clavi.

Discussion. Resemblance to '*Oppelia* (*Oecotraustes*)' *adela* Uhlig from the basal Spiti Shales is

apparently superficial. According to Uhlig (1910a, p. 72, pl. 43, fig. 3a–d), the holotype (only specimen) bears fine mid-ventral tubercles, i.e. a serrated keel, not seen by the illustrator.

We have received photographs of the supposed holotype (no. 7837) from the Indian Geological Survey which show septation on the last half-whorl and no egression of the large umbilicus, indicating that this is an inner whorl. The minute protuberances at mid-venter appear to sit on the partially exposed siphuncle, whereas the venter is generally rounded. It is possible that the protuberances are conellae, i.e. diagenetic products of a keel floor. This species therefore differs significantly from our *Jeanneticeras*. S. Elmi has seen the photographs and commented that '*O.*' *adela* appears to be very close to the middle Late Callovian *Putealiceras*.

Remarks and occurrence. The specimen was identified for us from photographs by S. Elmi and dated as latest Early Callovian (late Calloviense/Gracilis Zone). *J. anomalum* has been known only from the *Chanasia ardescica* Subzone of south-east France and is said to be an excellent guide.

<div align="center">

Family OTOITIDAE Mascke, 1907
Genus PSEUDOTOITES Spath, 1939
Pseudotoites? cf. *sphaeroceroides* (Tornquist, 1898)

</div>

1953   *Emileia* (*Frogdenites*) sp.; Arkell, pl. 13, fig. 4a–c.

Material. Arkell's (1953) description of a single immature specimen K9/249 from our loc. 1.

Remarks. The specimen is a very small (d = 18 mm), rather evolute cadicone with spinous nodes at the furcation point of dense ribs, close to the umbilical margin. This specimen does not permit even generic identification and could be the inner whorls of either micro- or macroconch. It is similar to the extremely rare north-west European *Frogdenites*, but also resembles juvenile *Emileia* and, especially, the common Pacific *Pseudotoites*.

Age and distribution. The genus *Pseudotoites* is known from the Laeviuscula Zone of south Alaska, the Southern Andes, Western Australia, and Indonesia. Inflated species resembling *P. sphaeroceroides* from the Andes occur also in Western Australia, i.e. *P. corona* (Arkell *in* Arkell and Playford 1954).

<div align="center">

Family SPHAEROCERATIDAE Spath, 1920
Subfamily MACROCEPHALITINAE Salfeld, 1921
Genus MACROCEPHALITES Zittel, 1884
Macrocephalites cf. *macrocephalus* (Schlotheim, 1813) ♀

Plate 21, figs. 1–2

</div>

Material. The poorly preserved specimen NIGP 84775 from unit 12 of loc. 18, North Tibet.

Remarks. The entirely septate shell is large, involute and sub-globular. The outer flanks and venter are covered by dense, fine ribs, approximately forty per quarter-whorl; the inner flanks (corroded) were either smooth or had only extremely blunt primaries. These features are typical for the group *M. macrocephalus* (for definition of the species see Callomon 1971, 1980). The complicated suture has a subradial saddle envelope and the laterodorsal parts of the septum are not oblique to the shell radius as in Eucycloceratinae and Mayaitinae.

Age and distribution. *M. macrocephalus* is well known from the (?)Macrocephalus Zone of Europe.

<div align="center">

Macrocephalites? cf. *etheridgei* (Spath, 1928) ♂

Plate 21, figs. 3–4

</div>

cf. * 1928   *Kamptocephalites etheridgei* Spath, p. 200, pl. 69, fig. 3 [holotype refigured].

Material. One fragment with incomplete body-chamber NIGP 84774 from levels C1–2 of loc. 8.

Remarks. This relatively evolute sphaeroceratid has the septal suture of *Macrocephalites s.l.* (Thierry 1978), i.e. the saddle envelope is subradial and not protracted as in the otherwise similar '*Grayiceras*'.

There is good resemblance to *M. etheridgei* also in the inflated whorls with steep umbilical slope and well-developed umbilical shoulder.

Age and distribution. *M. etheridgei* is known from the Upper Bathonian–Lower Callovian of eastern Indonesia and New Guinea (Sato 1975; Westermann and Callomon, unpubl.).

Subfamily EUCYCLOCERATINAE Spath, 1928

The family-group taxon Grayiceratidae was introduced by Spath (1925) in a paper on Somali fossils, based on a dubious nominate genus—and as obscurely 'deleted' by him 3 years later (Spath 1928, p. 224) by 'replacing' it with the (Tithonian) 'Paraboliceratidae' (the newly examined septal suture of the genotype was considered to be 'perisphinctoid'). The name Grayiceratidae was therefore suppressed in favour of the Mayaitidae Spath, 1928 by the International Commission on Zoological Nomenclature, opinion 471 (Henning 1957), based on Arkell's (1955) submission that the nominate genus is a *nomen dubium* (see below).

The family Eucycloceratidae Spath, 1928 was founded for the Callovian homoeomorphs of the Oxfordian Mayaitidae Spath, 1928; included in the Macrocephalitidae without distinction in the '*Treatise*' (Arkell *in* Arkell *et al.* 1957); retained at least at subfamily level by Westermann (1968) as the postulated phyletic intermediate between Macrocephalitidae and Mayaitidae; and questionably retained as a subfamily of the Sphaeroceratidae in the most recent classification by Donovan *et al.* (1981). Four genera, all from the latest Early–early Middle Callovian of the Indo-East African–Madagascan area (Ethiopian Province), were originally included in the family: *Eucycloceras* Spath, 1924 (type species *Stephanoceras eucyclum* Waagen), *Subkossmatia* Spath, 1924 (*Ammonites opis* J. de C. Sowerby), *Idiocycloceras* Spath, 1928 (*I. perisphinctoides* Spath), and *Nothocephalites* Spath, 1928 (*N. asaphus* Spath). They differ from macrocephalitins in the protracted, sometimes arched and simplified septal suture, and in the egressing body-chamber which is particularly coarsely ribbed, even in the macroconch of *Idiocycloceras*.

The Mayaitinae Spath, 1928, also restricted to south-eastern Tethys, have usually been regarded as being confined to the Upper Oxfordian (when divided into two substages). Although many mayaitins perfectly resemble the eucycloceratins, the supposed Late Callovian–Early Oxfordian gap swayed most researchers to derive the mayaitins from the Callovian–Oxfordian Pachyceratidae (e.g. Arkell *et al.* 1957). Westermann (1957), however, disregarded the supposed gap in the record and, based on a comparison of septal morphology, proposed that the eucycloceratins are the phyletic intermediates between macrocephalitins and mayaitins. Recently, Thierry (1975) has confirmed the identity in sutural ontogeny between macrocephalitins and mayaitins, and Westermann (*in* Sato *et al.* 1978) documented Early Oxfordian (Cordatum Zone) *Epimayaites* with typically protracted sutures in the Sula Islands, Indonesia. The recent arguments of Donovan *et al.* (1981) against a direct relationship between eucycloceratins and mayaitins is based on the old records from Kachchh, India (Spath 1927–1933) where *Epimayaites* occur mainly above *Mayaites*. The latter genus is characterized by more inflated whorls and a suture with radial saddle envelope. We also point out that the Upper Callovian–Lower Oxfordian tends to be represented by a hiatus due to world-wide eustatic regression, and often is poorly documented by ammonites in the Tethyan Realm.

The macroconch *Epimayaites* Spath, 1928 and the microconchs *Paryphoceras* Spath, 1928, *Dhosaites* Spath, 1924, and *Prograyiceras* Spath, 1928 are all characterized by protracted sutures

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EXPLANATION OF PLATE 21

Figs. 1 and 2. *Macrocephalites* cf. *macrocephalus* (Schloth.), (♀), NIGP 84775, unit 12 of loc. 18 in North Tibet, × 1.

Figs. 3 and 4. *M.?* cf. *etheridgei* (Spath), (♂), NIGP 84774 (coll. FdIV-11), damaged phragmocone with incomplete body-chamber, levels C1–2 of loc. 3, × 1.

PLATE 21

WESTERMANN and WANG, *Macrocephalites*
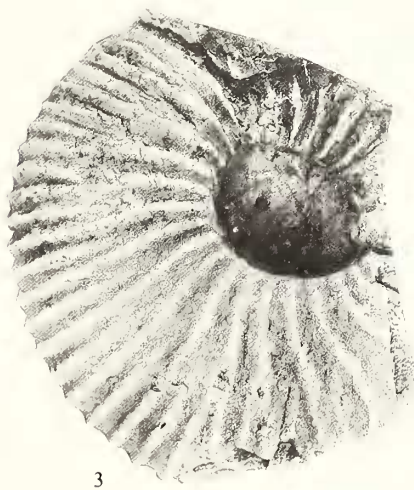
(opposite of retracted), coarsening body-chamber ribbing often even on the flanks of the macroconchs, variable ventral rib projection, and egression of the terminal body-chamber; these are all features shared with the eucycloceratins. Only the macroconch of *Mayaites* Spath, 1924 is said to differ by the straight ribs and subradial suture. But it remains unknown whether transitions exist among contemporaneous assemblages (populations?), i.e. whether *Mayaites* is a separate clade from *Epimayaites*. A study of Spath's monograph reveals that the sutures were often drawn with little attention to radial orientation, and that the umbilical elements of *Mayaites* nearest to the seam are consistently vertical to inclined away from the seam. This contrasts with *Macrocephalites s.l.* where these elements (U_3+?) incline towards the seam, i.e. they are vestiges of retracted umbilical (sutural) lobes. Spath divided the mayaitid macroconchs according to straightness of the secondaries and/or sutural inclination. But he also separated them stratigraphically by placing the slightly earlier forms from the Dhosa Oolite of Kachchh in *Mayaites* and those from the higher Kontkote Sandstone into *Epimayaites*, even when contradicted by morphology and suture, e.g. '*E.*' *axioides* Spath. The suture is unknown from several 'species', and similar variations in sutural inclination and ventral ornamentation exist in the Callovian eucycloceratins, especially *Idiocycloceras*. We are therefore inclined to believe that the Oxfordian mayaitins form a single clade, and may even belong to a single dimorphic genus with interspecific and intraspecific morphologic variation resembling that of *Macrocephalites s.l.* (Westermann and Callomon, unpubl.).

The only marked morphologic distinction of the Callovian eucycloceratins from the Oxfordian mayaitins as illustrated in the Kachchh monographs (Waagen 1875; Spath 1927–33) is the apparent absence of *Subkossmatia* macroconchs. A cursory inspection of a eucycloceratins collection from Jaiselmer (north of Kachchh), made by Jai Krishna, however, indicates the scarce presence not only of incomplete macroconchs of *S.* cf. *opis* closely resembling *Epimayaites* ♀ (together with its much more abundant microconch), but even the possible presence of '*G.*' *nepaulense* (Gray).

We conclude that the root of the mayaitin clade is in the eucycloceratins of the latest Early Callovian *S. opis* zone (Jai Krishna and Westermann 1985), branching off from late, but not the latest macrocephalitins. Eucycloceratins hardly differ at the family-group level from mayaitins and may therefore be combined in the Mayaitinae Spath, 1928 (a much more frequently used name than Eucycloceratinae, erected in the same paper). Additional work on eucycloceratins of Western India and Madagascar (also ?Kenya) is required to decide on the classification.

Genus GRAYICERAS Spath, 1923

History of genus name. The complicated history of the genus was detailed by Arkell (1955) who concluded that the name is a *nomen dubium*; it should not be used unless new field evidence becomes available. Together with Mr D. Phillips (Keeper of Ammonites), Westermann has examined the British Museum (Natural History) type collections.

Spath (1923) based the genus-group name *Grayiceras* on 'the group of *Simbirskites nepalensis* [*recte nepaulensis*] and *S. mexicanus* Burckhardt' (our brackets); in the following year Spath (1924) again named 'the new genus *Grayiceras*', with the 'genotype *G. blanfordi* n. sp. = *S. nepaulensis* Blanford 1865: *non* Gray, in Uhlig [1910a]'. Thus Spath created two homonymous genera based on different type species, and the first designation stands.

Type species. We support the opinion of Crick (1903), Uhlig (1910a), and Arkell's proposal (1955) that Blanford's type specimen of *S. nepaulensis*, i.e. the holotype of *G. blanfordi* (refigured by Uhlig 1910a, pl. 45A, fig. 1a–c) is very probably the same as *A. nepaulensis* Gray (1830–1832). *G. blanfordi* therefore appears to be a junior synonym of *A. nepaulensis* which then becomes the type species of *Grayiceras*. The probable lectotype (Blanford *in* Salter and Blanford 1865) of *G. nepaulensis*, however, is not Gray's syntype of figure 1 as assumed by Crick, but that of his figure 2 which was mislaid or unrecognized at Crick's time. Both syntypes are here reproduced photographically for the first time (Pl. 22; Pl. 23, fig. 1), noting that indubitable identification of the specimens with the brush illustrations of Gray will remain impossible. The probable lectotype bears the label 'Spiti' and the remaining syntype (paralectotype) 'Niti Pass', whereas Gray recorded 'Sulgrances', westernmost Nepal. The labels appear to be of a later date. The age of the specimens even as

to stage is also unknown since the specimens were probably collected loose if not purchased, and the type locality has not been revisited.

Although our fragmentary specimens from the Early Callovian of Tibet closely resemble *G. nepaulense*, the homoeomorphism with Oxfordian microconchs of *Paryphoceras* (♂) is so close that we cannot be sure of specific or even generic identity within the present classification. The marked egression of the terminal body-chamber in the lectotype cannot be compared with our specimens because of their incomplete preservation, and the generic affinity of the Early Callovian *G.? waageni* and *gucuoi* with normally coiled body-chambers, remains uncertain. The age of the lectotype *G. nepaulense* could therefore possibly be Oxfordian as assumed by Uhlig (1910*a*, *b*, 1911), Spath (1927–1933), and Arkell (1956), rather than Callovian. Consequently, the generic name *Grayiceras* remains something of an enigma. We therefore use queries or inverted commas, rather than creating a new genus based on our poor material.

Affinities. Besides the type species, Spath (1927–1933, p. 224) also placed '*S. koeneni*' Uhlig in *Grayiceras* and noted that '*M.*' *waageni* and *kitcheni*, Uhlig spp., are intermediate between *Grayiceras* and *Epimayaites*. The '*S. koeneni*' holotype (the only specimen), however, is a large body-chamber resembling the Callovian '*Subkossmatia ramosa*' Spath ♀ and *I. singulare* Spath ♀ from Kachehh; but the specimen is too incomplete for stricter comparison and therefore a *nomen dubium*. The small '*M.*' *waageni* and the probably conspecific '*M.*' *kitcheni* are relatively abundant in South Tibet and almost perfect homoeomorphs of the Oxfordian *Epimayaites*. The body-chamber is coiled more or less normally, however, and the ribbing is not modified on the mature ultimate whorl as in all microconchs of other Callovian–Oxfordian Eucycloceratinae and Mayaitinae. The septal suture is strongly protracted, distinguishing *G.? waageni* (including '*M.*' *kitcheni*) from compressed *Macrocephalites* microconchs, i.e. '*Dolikephalites*'. *G.? gucuoi* n. sp., similarly, closely resembles inflated, evolute *Macrocephalites* microconchs (♂), i.e. '*Kamptokephalites*', and also Oxfordian *Dhosaites* ♂.

The Late Oxfordian *Prograyiceras*, type species *P. grayi* Spath, is distinguished by the much coarser and strongly projected secondary ribs. The Callovian mayaitin closest to *Grayiceras* is probably *Eucycloceras eucychum* (Waagen) which has septate whorls similar to *G. nepaulense* and *G.? waageni*, but differs in the ornamentation of the body-chamber. *Subkossmatia* is more compressed with denser, prosocline ornamentation. *G.? gucuoi* resembled *Idiocycloceras* from Kachehh but differs in the broader whorls bearing shorter primaries. All eucycloceratins, however, differ in the trapezoidal, not rounded, inner whorls with vertical umbilical slope and sharp margin.

(?)*Grayiceras nepaulense* (Gray, 1830–1832) (♀ ?)

Plate 22; Plate 23, fig. 1; text-fig. 12A–B

cf. v * 1830–1832   *Ammonites nepaulensis* Gray, pl. 10, figs. 1 and 2 [lectotype].
cf. v   1865   *Ammonites nepalensis* Gray; Blanford in Salter and Blanford, p. 77, pl. 14, fig. 1*a*, *b*.
non v   1875   *Stephanoceras nepaulense* Gray; Waagen, p. 136, pl. 35, figs. 2 and 3 [= *Prograyiceras grayi* Spath].
cf.   1910*a*   *Simbirskites nepaulensis* Gray; Uhlig, p. 271, pl. 45A, fig. 1*a–c* [Blanford, 1865, refigured].
cf. v   1924   *Grayiceras blanfordi* Spath, p. 11 [for Uhlig, 1910].
cf. v   1928   *Grayiceras blanfordi* Spath, p. 224, pl. 27, fig. 3 [septal suture of holotype].

Lectotype. The almost complete, fully grown lectotype of *G. nepaulense* (Pl. 22) has a slightly compressed elliptical whorl-section with rounded umbilical shoulders and a rather narrow, evenly curved venter. The body-chamber, preserved with two to three whorls, was about three-quarters of a whorl long. It egresses markedly only with the ultimate quarter-whorl. The ribs consist of gently curved primaries which increase in prominence and length on the body-chamber, and subfasciculate to ataxiocerid secondaries which form a moderately convex arc on the venter. The primaries reach maximum height at mid-flank on the phragmocone, but extend to two-fifths whorl height on the adult body-chamber. The suture is moderately complicated with deep E and L lobes followed by three much smaller U lobes. The saddle envelope rises strongly toward the umbilical seam, i.e. the suture is protracted.

Measurements. In mm of lectotype (C25182).

	d	b	h	b/h	u
Near aperture	120	48	55	0·87	29 (0·24)
End phragmocone	102	∼29	33	∼0·95	21·5(0·20)
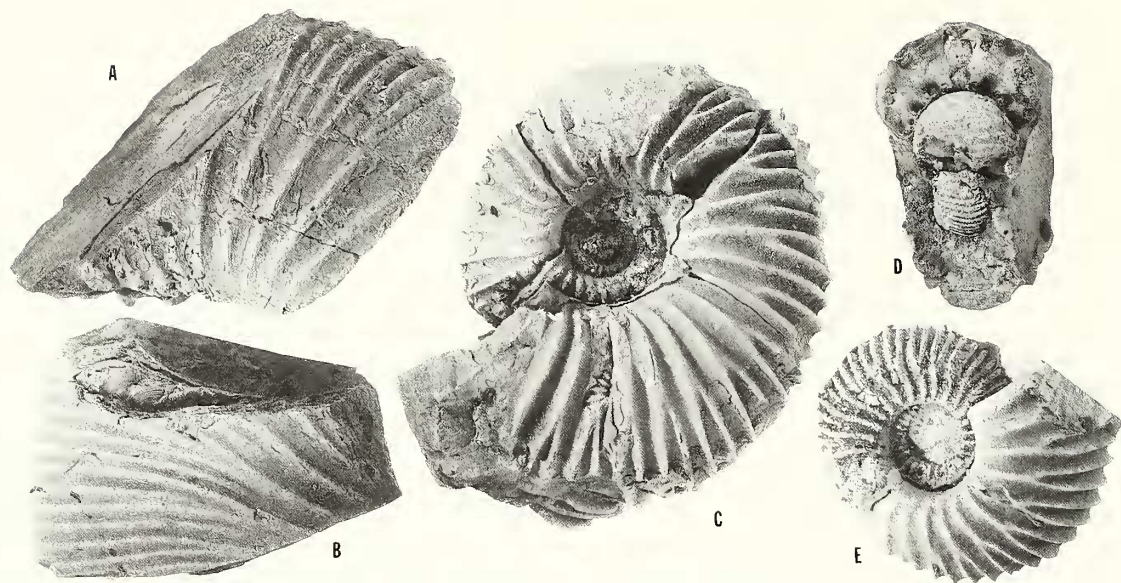
TEXT-FIG. 12. 'Grayiceras' Association. A, B, probable *G. nepaulense* (Gray) body-chamber fragments, from loc. 13, × 1. A, J2182*b*, from bed A1; B, J2188*b*, from bed B1. C–E, *G.? gucuoi* n. sp., from bed A5, loc. 13, × 1. C, D, J2177*a*, complete specimen with latex cast of phragmocone; E, J2178*b*, incomplete body-chamber with latex mould of phragmocone.

Material. Two fragments of large body-chambers, J2182*a*, *b*, one with last septum, from bed A1, and several fragments, J2188, from bed B1, loc. 13.

Descriptions. The whorl section is subcircular-ovate, slightly depressed (b = 43·5 mm, h = 41·5 mm), with maximum width at two-fifths whorl height and steep umbilical slope. The section resembles that of the lectotype at the equivalent growth stage, i.e. the beginning of the body-chamber at about 90 mm diameter. The long, prominent primaries divide at three-fifths whorl height into slightly projected secondaries and some ribs are intercalated, just as in the lectotype; the primaries on our specimens vary in degree of flexure, some being as flexuous as in the lectotype. The septal suture is strongly protracted, with the entire septal surface being inclined to the whorl section by *c.* 35°.

Discussion. Our fragments closely resemble the lectotype. The strongly oblique umbilical seam in Spath's (1928, pl. 27, fig. 3) illustration of the lectotype indicates that the suture is much more protracted than shown by him. For comparison with other species, see under genus.

<div align="center">

Grayiceras? *waageni* (Uhlig, 1910) (♂?)

Plate 23, figs. 2–5; Plate 24, figs. 1–6; text-fig. 13

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  * 1910*a* *Macrocephalites waageni* Uhlig, p. 270, pl. 77, figs. 1, 2*a*, *b*, 3*a*–*c*.
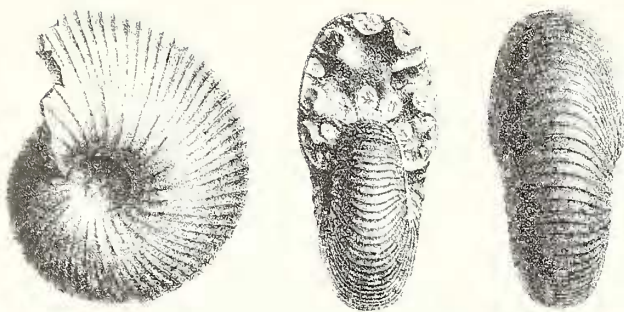 ? 1910*a* *Macrocephalites kitcheni* Uhlig, p. 271, pl. 77, fig. 6*a*–*d*.
  v   1976   *Macrocephalites compressus* (Quenstedt); Zhao, pl. 5, figs. 1–3.

<div align="center">

EXPLANATION OF PLATE 22

</div>

Figs. 1–3. *Grayiceras nepaulense* (Gray), lectotype [holotype of *G. blanfordi* Spath], British Museum Nat. Hist. C25182, from 'Spiti' (label) or 'Sulgraness' (text), × 1.

PLATE 22

3

2

1

WESTERMANN and WANG, *Grayiceras*
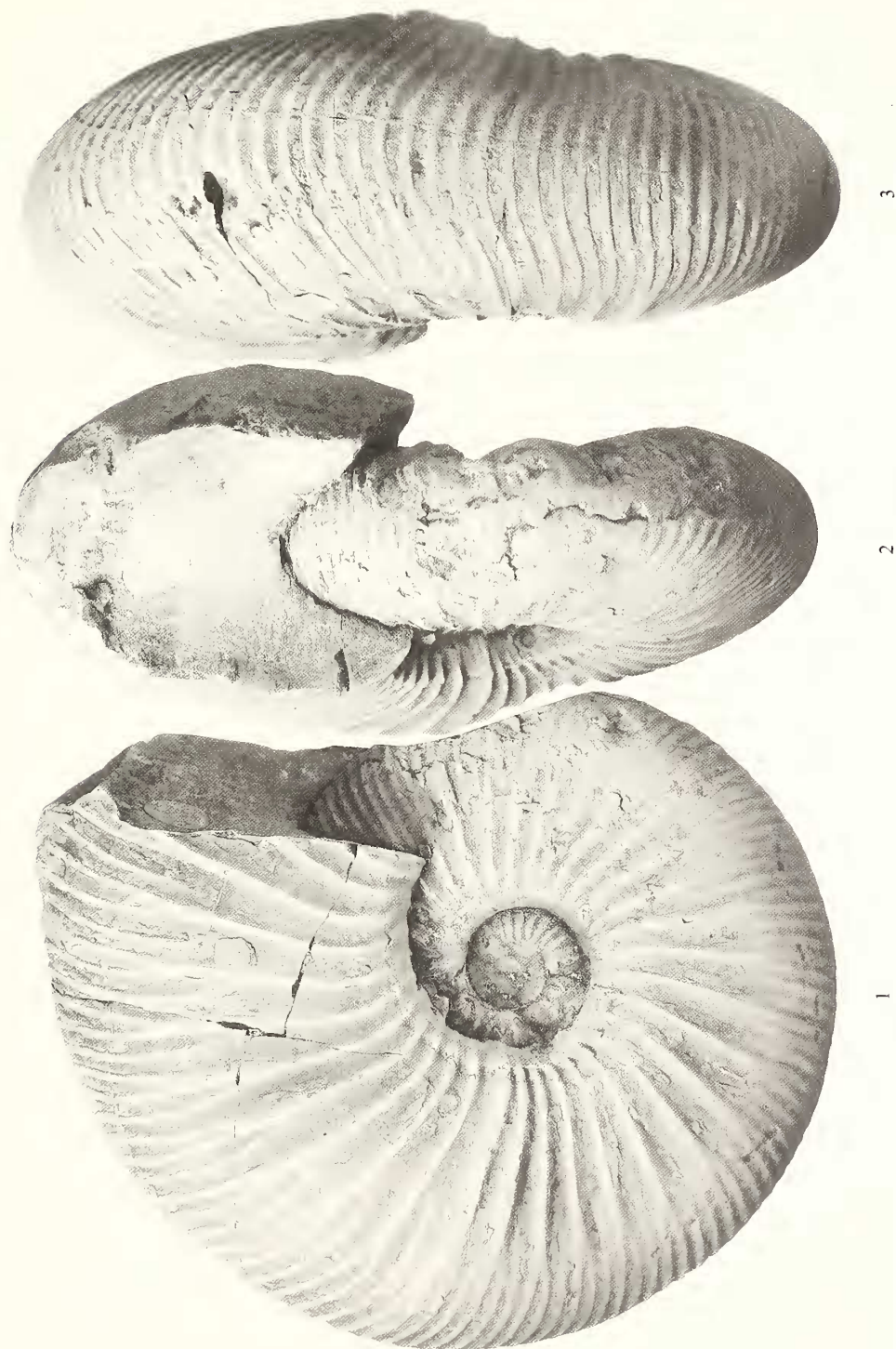
TEXT-FIG. 13. *Grayiceras*? *waageni* (Uhlig), reproduction of Uhlig's illustration (1910*a*, pl. 77, fig. 3*a–c*, Geol. Surv. India no. 10030), × 1, from 'Gieumal', Spiti. This specimen was used to 'characterise the new species' and clearly shows the oblique (protracted) septum; but the specimen is now badly deteriorated by pyrite oxidation (see also Pl. 23, figs. 4–6).

v   1976   *Dolikephalites* cf. *typicus* (Blake); Zhao, pl. 7, fig. 79; pl. 7, fig. 10; pl. 12, figs. 1 and 2.
v ? 1976   *Macrocephalites* sp. 1; Zhao, pl. 6, figs. 7 and 8.
v ? 1979   *Dolicephalites* sp.; Wang and Cheng *in* Wang *et al.*, pl. 17, figs. 1 and 2.
     1985   *Macrocephalites compressus* Quenstedt; Wang, pl. 1, fig. 1*a, b*.

Lectotype. Here designated: Uhlig, 1910*a*, pl. 77, fig. 2*a, b* (Geol. Sur. India no. 10026), a somewhat crushed but probably almost complete shell of 65 mm diameter, from 'Gieumal' (Giumal) in Spiti area.

We have received new photographs from the Geological Survey of India (Calcutta) of the three syntypes from 'Gieumal'. The small (d = 35 mm) and entirely septate specimen (Geol. Sur. India no. 10027; Uhlig 1910*a*, pl. 77, fig. 3*a–c*) was said to be the best-preserved specimen 'which has been chiefly made use of in establishing the character of the species'. Unfortunately, this specimen has meanwhile deteriorated so badly (pyrite oxidation) that it cannot be designated as the lectotype. It also did not show the typical ornamentation of the outer whorl. The two larger syntypes, of which the best is here designated as the lectotype, are both somewhat crushed, but otherwise satisfactorily preserved. The photo of the lectotype shows the septal suture (probably protracted) at about three-fifths of the whorl before the broken end of what appears to be the body-chamber. The primary costae become very prominent and markedly curved; the whorls are involute and were originally more or less strongly compressed ovate; the venter is narrowly convex and crossed by prominent sharp ribs.

Material. Specimens NIGP 30435–30436, 30470 from loc. 8; specimens NIGP 30439 and ?30446 from beds Kp3, 4 of loc. 10; fragmentary body-chambers J2180*a–e*, one of which has mould of incomplete phragmocone, from bed A5, and (?) two juvenile specimens, J2181*a, b* from bed A1, loc. 13; specimens A058 and ?A057 from loc. 14.

Description. An involute, small species (or microconch) with subtrapezoidal whorls, somewhat compressed to as broad as high. The narrow size range of our body-chamber fragments indicates a full diameter of only 60–70 mm and our largest specimen has approximated sutures at 46 mm diameter, in good agreement with the type series. Ribbing is dense, sharp where the shell is preserved, and highly prominent and more or less strongly flexed on the inner flank. There are about fifteen to twenty primaries and forty to fifty secondaries per half-whorl. The primaries are concave and divide irregularly near mid-flank into the less prominent secondaries; some ribs are

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EXPLANATION OF PLATE 23

Fig. 1. *Grayiceras nepaulense* (Gray), paralectotype, British Museum Nat. Hist. C5052 [original to Gray, pl. 100, fig. 1], from 'Niti Pass' (label) or 'Sulgraness' (text).

Figs. 2–5. *G.*? *waageni* (Uhlig). 2, 3, lectotype, probably almost complete but somewhat crushed, lateral and ventral views (Uhlig 1910*a*, pl. 77, fig. 2*a–b*) from 'Gieumal, Spiti'. 4, 5, specimen in the British Museum Nat. Hist. collection, closely similar to paralectotype illustrated in text-fig. 13, unlabelled but stored together with syntypes of *B. nepaulense* and same preservation.

Figs. 6, 7. *G.*? aff. *waageni* (Uhlig), NIGP 30445, from units Kp1–4 of loc. 10.

Figs. 8, 9. *Subkossmatia* cf. *opis* (J. de C. Sow.), J2178*b*, from bed A5 of loc. 13.

All figures × 1.

PLATE 23

WESTERMANN and WANG, *Grayiceras, Subkossmatia*

intercalated. The ratio of secondaries to primaries is approximately 2:5. The secondaries are rectiradiate to slightly prorsiradiate and cross the venter straight to weakly convex, becoming markedly convex on the second half of the body-chamber. The body-chamber shows no significant change or only slight reduction in coiling, at least with the first half-whorl. The aperture is unknown. The septum is typically bullate, with two complete (paired) saddle and lobe axes, and markedly inclined to the radial plane (about 20°); the suture is therefore strongly protracted. Sutural complication is moderate with a graded sequence of lobes and saddles along the protracted saddle envelope.

Measurements. In mm (J2180*a*).

	d	b	h	b/h	u
Body-chamber	65	31·5	33	0·95	11·2(0·17)
End phragmocone	46	22·4	~21·5	~1·05	9·0(0·20)

Discussion. Our specimen closely resembles the illustrations of the syntypes (type series) collected by Stoliczka at 'Gieumal' in Spiti valley, and the only specimen (holotype) of '*M. kitcheni*' Uhlig from the same collection. The holotype of '*M. kitcheni*', however, is now badly disintegrated due to pyrite oxidation (new photo received) and no longer serves as a type specimen. The original illustration (Uhlig 1910*a*, pl. 77, fig. 6*a–c*) indicates that the holotype was close to, and probably a conspecific variant of, *G.? waageni* (Uhlig's illustration does not show the 'strongly deflected forward' ornamentation mentioned in his text). Sutural complication is moderate with a graded sequence of lobes and saddles along the protracted saddle envelope.

There is rather close similarity to the microconch of *M. keeuwensis* Boehm (1912) from the Calloviensis/Gracilis Zone of the Sula Islands, except for the much more strongly protracted septal suture and the more prominent ribbing of *G.? waageni*. Significantly, that species has long been suggested as the hypothetical ancestor of the 'Euclycloceratinae' (Spath 1928). Almost perfect homoeomorphy exists, however, to the juvenile or inner whorls of the Oxfordian *Epimayaites*, e.g. the type species *E. transiens* (Waagen), or of its microconch *Paryphoceras*, which without stratigraphic control may be indistinguishable. Mayaitinae, however, tend to have variocostate ribbing in both dimorphs, with the microconchs getting extremely coarse ribs on the ultimate one or two whorls whereas macroconchs tend to become smooth, and with an egressing body-chamber.

G.? waageni could be a microconch, possibly to *G. nepaulense* whose inner whorls appear to be closely similar but are poorly known. But since both presumed dimorphs of '*Grayiceras*' appear to have some coarsening of ornamentation on the adult body-chamber, both forms could alternatively be microconchs of different species. *G.? waageni* could even be a macroconch of an even smaller form, but these latter may be juveniles and/or incomplete.

<p style="text-align:center">*Grayiceras?* aff. *waageni* (Uhlig)</p>

<p style="text-align:center">Plate 23, figs. 6 and 7</p>

? *v* 1976   *Indocephalites* aff. *transitorius* Spath; Zhao, pl. 8, figs. 10 and 11.
? *v* 1976   *Indocephalites* cf. *indicus* Spath; Zhao, pl. 6, figs. 3 and 4.

<p style="text-align:center">EXPLANATION OF PLATE 24</p>

Figs. 1–6. *Grayiceras? waageni* (Uhlig), from '*Grayiceras*' Association of Loc. 13. 1–4, body-chamber with latex cast of phragmocone, J2180*a*, bed A5. 5, body-chamber fragment, J2180*b*, bed A5. 6, almost complete juvenile(?), J2181*a*, from bed A1.

Figs. 7–14. *G.? gucuoi* n. sp., from bed A5 of loc. 13. 7–10, holotype, J2176, complete but phragmocone as latex cast. 11, J21772, complete juvenile(?). 12–14, J2177*b*, (?)juvenile body-chamber.

All figures × 1.

PLATE 24

WESTERMANN and WANG, *Grayiceras?*
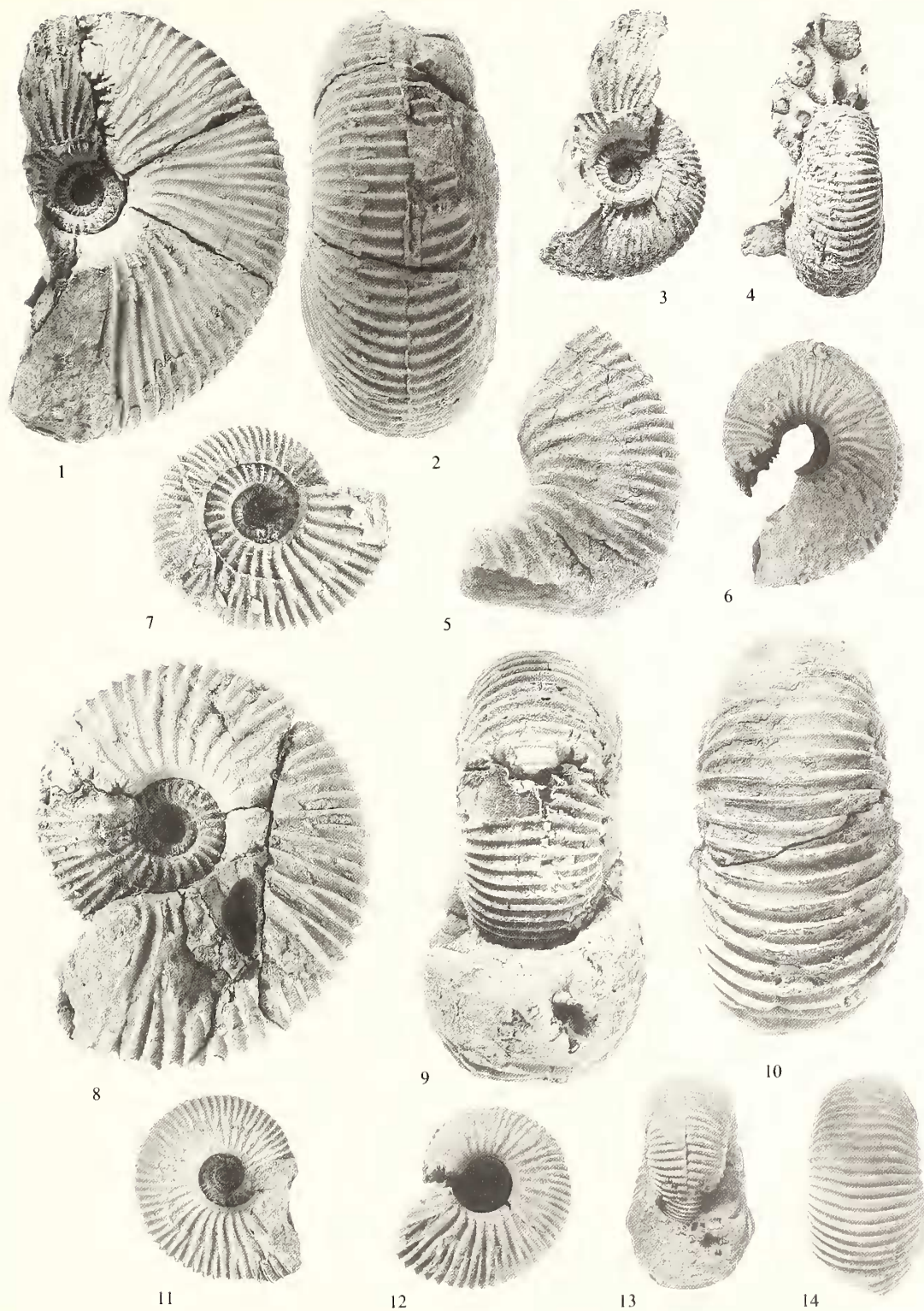
Material. Three incomplete and/or distorted body-chambers NIGP 30445, 30449, ?30437, ?84764, ?30440 from beds Kp1–4(6), loc. 10; possibly also NIGP 30438, 30441, and 30444 from loc. 9; fragments from beds A and Bl, loc. 13.

Description. The body-chamber is approximately 80–90 mm in diameter and three-quarter whorls long. Coiling is moderately involute (u/d = 0·20 to 0·25) with slight egression at the end. The whorl section is rounded-ovate, about as high as wide, to markedly depressed. The ribbing is sharp and dense, with about twenty concave primaries and forty-five to fifty secondaries per half-whorl. The primaries divide irregularly (subfasciculate) at about mid-flank into two or three secondaries which, together with some intercalated ribs, cross straight over the venter. The septal suture is strongly protracted.

Discussion. This form has the ornamentation of *G.? waageni* but differs in the more inflated, depressed whorls and the somewhat larger size. *G. nepaulense* has a similar whorl section, but differs in the larger size and the much coarser costation on the body-chamber.

Almost perfect homoeomorphs are *Epimayaites subtumidus* (Waagen) and the dubiously distinct *E. axioides* Spath from the Upper Oxfordian of Kachchh, but their phragmocone has only biplicate ribs while the body-chamber is unknown from the type specimen.

Grayiceras? *gucuoi* n. sp. (♂?)

Plate 24, figs. 7–14; text-fig. 12C–E

? 1910   *Macrocephalites* sp., Uhlig, 1910, pl. 77, fig. 5a–c.
? 1958   *Idiocycloceras rebillyi* Collignon, pl. 21, fig. 86.
v? 1976   *Indocephalites diadematus* (Waagen); Zhao, pl. 6, figs. 5 and 6; pl. 5, fig. 45; pl. 7, figs. 3 and 4.
? 1985   *Indocephalites diadematus* (Waagen); Wang, pl. 1, figs. 5 and 6.

Holotype. The almost complete specimen J2176 with phragmocone, mould (latex cast), Plate 24, figs. 7–10, from bed A5 of loc. 13, 4 km upstream in valley from bridge at km 613/4 of Nyalam–Lhasa highway, Tethyan Himalaya, in South Tibet.

Name. Derived from village of Gucuo, north of type locality.

Other material. Five topotypes, J2177a–e, one of which is almost complete with phragmocone mould and the others incomplete and, in part, juvenile; two incomplete moulds, J2177a, b, from bed A5, loc. 13; probably also NIGP 84776–84778 from upper part and NIGP 30438 from bed Kp8, loc. 10.

Diagnosis. Small (♂?) with moderately evolute, depressed, subovate to elliptical whorls. Biplicate ribbing of increasing prominence to aperture, dividing at mid-flank, subradial with slight flexure and faint ventral convexity.

Description. Adult shell diameter is approximately 60–70 mm. The phragmocone is small (d = 25 to 40 mm), median evolute (u/d = 0·25 to 0·30) and thick-planulate (b/d = 0·57 to 0·63). The whorl section is ovate, and moderate to strongly depressed (b/h = 1·23 to 1·5), with steep, rounded umbilical slope, rounded flanks becoming slightly acute in the most depressed morphs, and evenly rounded venter. The prominent and sharp, biplicate ribbing tends to flex at mid-flank. The primaries arise near the umbilical seam, form a slightly to moderately concave arc on the umbilical slope and inner flank, and divide at or slightly below half whorl-height into two secondaries. The outer part of the primaries is blade-like. The secondaries tend to begin rursiradiate, become radial, and cross the venter with slight convexity.

The septum is typically bullate, with two (paired) complete saddle axes. The external and lateral saddles are subequal in size, the latter being higher than the former. The umbilical lobes are shallow and, together with their saddles, moderately to strongly protracted so that the intercept with the umbilical seam is as high as the umbilical saddle.

The body-chamber is approximately 300° (over three-quarters of a whorl) long. Their is no increase in the coiling rate, the umbilical width (u/d) remaining at 26–30 per cent of the diameter. The whorl section becomes only slightly more rounded, remaining depressed subovate to subelliptical with steep umbilical slope and broadly rounded venter. The ribs become extremely prominent, with blade-like profile on flanks and venter, even on the internal mould. The biplication is often asymmetric, the adoral secondary of each pair being initially higher than the adapical one. The adoral arc of the secondaries becomes more pronounced toward the aperture.

Measurements. In mm.

		d	b	h	b/h	u
Holotype	end body-chamber	66	33·5 (0·51)	28 (0·42)	1·2	18·9 (0·29)
	beg. body-chamber	40	22·5 (0·56)	17·4 (0·44)	1·24	11·6 (0·29)
	phragmocone	34	20·6 (0·61)	16·7 (0·49)	1·23	9·2 (0·27)
2177a	end body-chamber	62	∼34	∼25	∼1·36	16·4 (0·26)
	body-chamber	51	31	21·3	1·46	14·1 (0·28)
	end-phragmocone	∼35	21·8 (0·63)	14·6	1·49	9·1 (0·26)
2177b (juv.)	body-chamber	30	18·2 (0·60)	12·4 (0·41)	1·47	9·0 (0·30)
	body-chamber	24	13·5 (0·56)	9·3 (0·39)	1·45	7·4 (0·31)
	beg. body-chamber	18	11·2 (0·62)	7·5 (0·42)	1·14	—
2177c (juv.)	body-chamber	30·5	18·5 (0·61)	12·3 (0·40)	1·50	8·5 (0·28)
	body-chamber	24·1	14·0 (0·58)	10·3 (0·43)	1·36	6·6 (0·27)

Remarks. This species (microconch?) is much more evolute and inflated, and with much coarser ribbing than *G.? waageni*. No intermediates are known.

The approximate contemporary *Idiocycloceras* Spath of the Ethiopian Province shows the closest although modest affinity among reasonably well-known genera. *I. perisphinctoides* Spath, type species, was based only on the holotype which came from the 'sub-*anceps* bed' (*S. opis* Zone) of Habye, Kachchh. This 'genotype' is moderately preserved and incomplete at the mostly septate diameter of 90 mm and probably a microconch. Its whorls are subcircular with flattened flanks, rather than depressed-ovate, and markedly more evolute (u/d = 0·39) than in *G.? gucuoi*, at all growth stages, and the primaries are longer, whereas the septal suture is similar. *I. singulare* Spath 1928 is also based on the holotype only, *Stephanoceras fissum*, Waagen, *non* Sowerby, from the '*anceps* Zone' of Kachchh. This macroconch has never been illustrated photographically, but we have a plaster cast. At 162 mm diameter it has only the beginning of the body-chamber and is much more evolute (0·33 instead of 0·24) than shown by Waagen (1875, pl. 37, fig. 1) but was otherwise reasonably well illustrated. The inner whorls have a vertical umbilical slope with sharp margins and flat flanks. The outer whorl becomes subovate with narrowly rounded venter and changes from as wide as high, to moderately compressed (b/h = 0·83). The secondaries form chevrons at mid-venter. This could well be the macroconch to *I. perisphinctoides*, but also appears to be closely allied to large supposed *Subkossmatia*, e.g. *S. ramosa* Spath, from the same zone. *I. dubium* Spath was also based on the fragmentary holotype only, which differs from the genotype merely in the larger size, more compressed whorls, and the less protracted septal suture. All Kachchh *Idiocycloceras* have subtrapezoidal, evolute whorls tending to become compressed subovate, strong biplicate ribbing with long primaries and ventral projection on all whorls, and a more or less protracted septal suture. Thus, *Idiocycloceras* differs consistently in the trapezoidal, rather than elliptical to subovate, and more compressed section of the inner whorls, and in the longer primaries.

The much more abundant genus *Subkossmatia* from the same *S. opis* Zone of Kachchh, is distinguished by the more compressed whorl-section and the much more densely ribbed immature or septate whorls, but appears to be intimately related to *Idiocycloceras*. Additional collections, particularly of microconchs, are required to solve the taxonomic problems.

An evolute small specimen with depressed whorls and coarse ribbing described from the upper Lower Callovian of Madagascar under *Idiocycloceras rebillyi* Collignon (1958, pl. 21, fig. 86),

closely resembles our specimen. The illustrated 'type' appears to be adult with about 45 mm phragmocone diameter, but it is incomplete, damaged, undescribed, and not illustrated in ventral views. We have been unable to locate the holotype in the Collignon (Dijon) and Rebilli (Paris) collections.

The most amazing homoeomorphy, however, exists to some more or less contemporary *Macrocephalites* microconchs, i.e. '*Kamptocephalites*', with the principle exception of the septal suture, as well as to the Late Oxfordian mayaitin microconchs *Dhosaites otoitoides* Spath (including *D. primus* Spath), and *Prograyiceras grayi* Spath, even in the sutures.

Uhlig's (1910a, pl. 77) '*Macrocephalites* sp.' (= '*Stephanoceras* sp.' Uhlig 1911) from supposedly about 150 m below the Spiti Shales, resembles this species but, in the absence of the septal suture, could as likely be a *Macrocephalites* microconch as believed by Spath (1928).

Genus SUBKOSSMATIA Spath 1924

Presumably like the entire subfamily, this well-known genus is known only from the Ethiopian Province, i.e. Kenya, Madagascar, and Kachchh. The Indonesia–New Guinea examples belong either to *Macrocephalites* microconchs (Boehm 1912, pl. 38, fig. 1) or to a new genus of Bathonian Sphaeroceratinae ('*S. obscura boehmi*' Westermann and Getty 1970; Westermann and Callomon, unpubl.). In Kachchh, at least, the genus is restricted to the *S. opis* Assemblage Zone (Jai Krishna and Westermann 1985) of the uppermost Lower Callovian, with the possible and partial exception of '*S. ramosa*' Spath (1927–1933, pp. 215, 716). The latter name is a *nomen dubium*, being based on an insufficiently preserved holotype and is of controversial age.

Subkossmatia cf. *opis* (J. de C. Sowerby, 1840)

Plate 23, figs. 8 and 9

Material. Two fragments, J2179a, b, from bed A1 and three fragments, J2178a–c from bed A5, loc. 13.

Remarks. The holotype of this common type species of *Subkossmatia* was refigured by Spath (1927–1933, pl. 36, fig. 2; pl. 39, fig. 2a, b). Our fragments closely resemble this Kachchh species which, according to new field-work by Jai Krishna (pers. comm.), is abundant in the *S. opis* Zone and probably includes most of Spath's rare 'species' from the same beds, e.g. '*S. obscura*'. The whorls of the medium-size shell are compressed with dense, strongly prorsiradiate and projected ribbing on phragmocone and body-chamber.

The specimens from Spiti described by Uhlig (1910a, pls. 77 and 81) as '*Macrocephalites* cf. *maya*' and '*Simbirskites* n. sp. ind.' closely resemble *Epimayaites* as suggested by Spath (1927–1933), in particular *E. falcoides* Spath.

## Family PACHYCERATIDAE Buckman, 1918
Genus *Erymnoceras* Hyatt, 1900
Erymnoceras sp. nov. aff. *coronatum* (Bruguière, 1848)

Text-fig. 14A–E

v 1976   *Erymnoceras coronatum* (Bruguière); Zhao, pl. 7, figs. 1 and 2; pl. 9, figs. 5–6, 9–10.

Material. NIGP 30447, 13457, and 13458 from loc. 11.

Description. The largest of our three specimens has a diameter of about 210 mm. The shell is evolute and subcoronate, with wide and deep umbilicus, and a depressed whorl-section with broadly rounded venter. The narrow inner flank is covered by coarse blunt ribs. At mid-flank is a series of prominent nodes or bullae in which the ribs divide into two or three and, occasionally, four
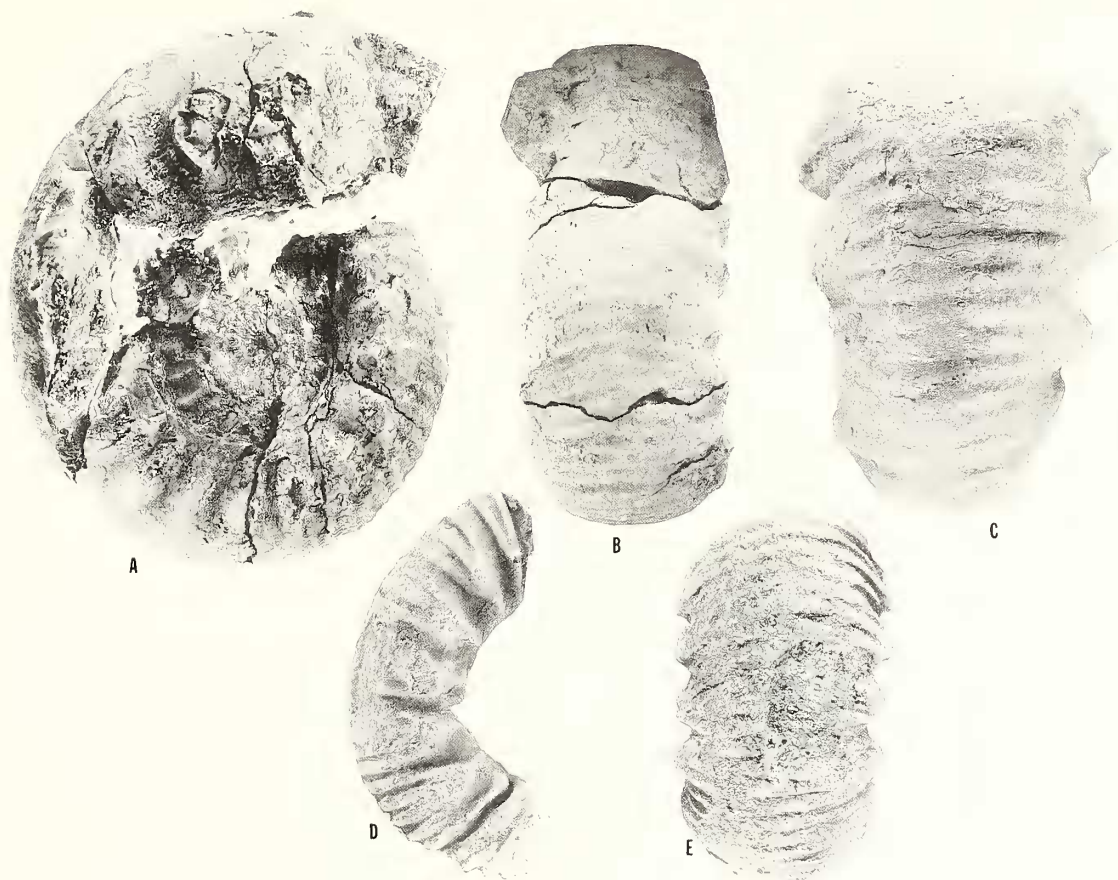
TEXT-FIG. 14. *Erymnoceras* sp. n. aff. *coronatum* (Brug.), from loc. 11. A–C, NIGP 30457, × 0·5. D, E, NIGP 30447, × 1.

secondaries; single intercalated ribs are also present. The secondaries thicken towards mid-venter which they cross.

Discussion. These specimens differ from the mid-Callovian, Tethyan *Erymnoceras coronatum* in the more depressed whorl-section, and appear to belong to a new, related species.

Age and distribution. *Erymnoceras* is restricted to the Middle Callovian of the Tethyan Realm, mainly western Europe, but has recently also been found in Kachchh, India (Jai Krishna and Cariou 1986).

Family PERISPHINCTIDAE Steinmann, 1890
Subfamily PSEUDOPERISPHINCTINAE Schindewolf, 1925
Genus CHOFFATIA Siemiradzki, 1898
Choffatia cf. *madani* Spath, 1931

Plate 25, figs. 3–5

v 1976 *Choffatia madani* Spath; Zhao, p. 526, pl. 8, figs. 1 and 2; pl. 9, figs. 11 and 12; pl. 10, figs. 7 and 8; pl. 13, figs. 7 and 8; non pl. 8, figs. 3 and 4.

Material. NIGP 30448, 30455, 30461, 30474 from the *Choffatia* assemblage of loc. 10.

Description. The whorls are evolute (u $\simeq$ 48 %) and compressed subtriangular with rounded venter and vertical, low umbilical wall. The primary ribs are coarse, strong, and limited to mid-flank, while the fine secondaries arise by bifurcation or trifurcation and tend to weaken toward the aperture. The septal suture is complex with wide and large **E** lobe and very long **L** lobe. The present species is therefore considered to belong to the Early Callovian *C. perdagatum–balinensis* group.

Age and distribution. *C. madani* was described only from the '*Rehmanni* Zone' ($\simeq$ Calloviense/Gracilis Zone) of Kachchh, India (Spath 1927–1933, pl. 67, fig. 1).

<div align="center">

Choffatia cf. *balinensis* (Neumayr, 1871)

Plate 25, figs. 6–8

</div>

cf. 1970   *H.* (m. *Homeoplanulites*) *balinensis* (Neumayr); Mangold, p. 68, figs. 44 and 46; pl. 6, figs. 1, 2, 3 [with complete synonymy].

v 1976   *Choffatia obtusecostata* Zhao, 1976, pp. 526–527, pl. 9, figs. 3 and 4; pl. 11, figs. 7 and 8; pl. 7, figs. 5 and 6 [*nomen dubium* and homonym].

v 1976   ?*Subkossmatia* sp.; Zhao, p. 525, pl. 7, figs. 5 and 6.

Material. Fragments NIGP 30455 and 30448 from units Kp14–18, loc. 10.

Remarks. The whorls are compressed elliptical with narrowly rounded venter and rather wide umbilicus. Their ornamentation in particular makes the present specimens very similar to Spath's (1927–1933, pl. 48, fig. 8) *C. baluchistanensis* (Noetling) from the middle Lower Callovian of Kachchh. That species, as Spath indicated, is extremely close to *C. balinensis*, and a synonym according to Mangold (1970). '*C. obtusecostata*' Zhao is deleted for two reasons. The fragmentary type material is undiagnostic for a new species, and the name is homonymous with *C. obtusicostata* (Waagen 1875) from which it differs only by substituting the letter 'e' for 'i'.

Age and distribution. *C. balinensis* is known from the lower Calloviense/Gracilis Zone of the Ethiopian and Mediterranean provinces.

<div align="center">

Choffatia cf. *funata* (Oppel, 1857)

Plate 25, fig. 9

</div>

cf. 1970   *H.* (*M. Parachoffatia*) *funatus* (Oppel); Mangold, p. 80, figs. 51–53; pl. 7, fig. 5 [with complete synonymy].

Material. NIGP 84770 from loc. 12; fragment J 2185 from bed A5 of loc. 13; NIGP 84771 from loc. 17; slightly crushed NIGP 84772 and 84773 from loc. 18.

Description. The shells are evolute, compressed with subparallel flanks, rounded venter and rather wide umbilicus. The primaries are slightly blunt at the umbilical margin and on the inner flank. They divide into two to four secondaries near mid-flank and cross the venter.

Discussion. These specimens can be compared with Mangold's specimens of *C. funata* (Mangold 1970, pl. 7, fig. 5) in size, coiling, whorl-section, and especially ornamentation.

<div align="center">

EXPLANATION OF PLATE 25

</div>

Figs. 1 and 2. *Choffatia* (*Grossouvria*) *propinqua* (Uhlig), ♂, J2184, almost complete but phragmocone as latex cast, '*Grayiceras*' Association from bed A5 of loc. 13, × 1.

Figs. 3–5. *C.* cf. *madani* Spath, from loc. 10.   3, NIGP 30474, × 0·6.   4, NIGP 30455, × 1.   5,

Figs. 6–8. *C.* cf. *balinensis* (Neum.), from loc. 10.   6, NIGP 30455, × 1.   7 and 8, NIGP 30448, × 1.

Fig. 9. *C.* cf. *funata* (oppel), NIGP 84772 (coll. 76 CDMI), from loc. 18, × 1.

PLATE 25
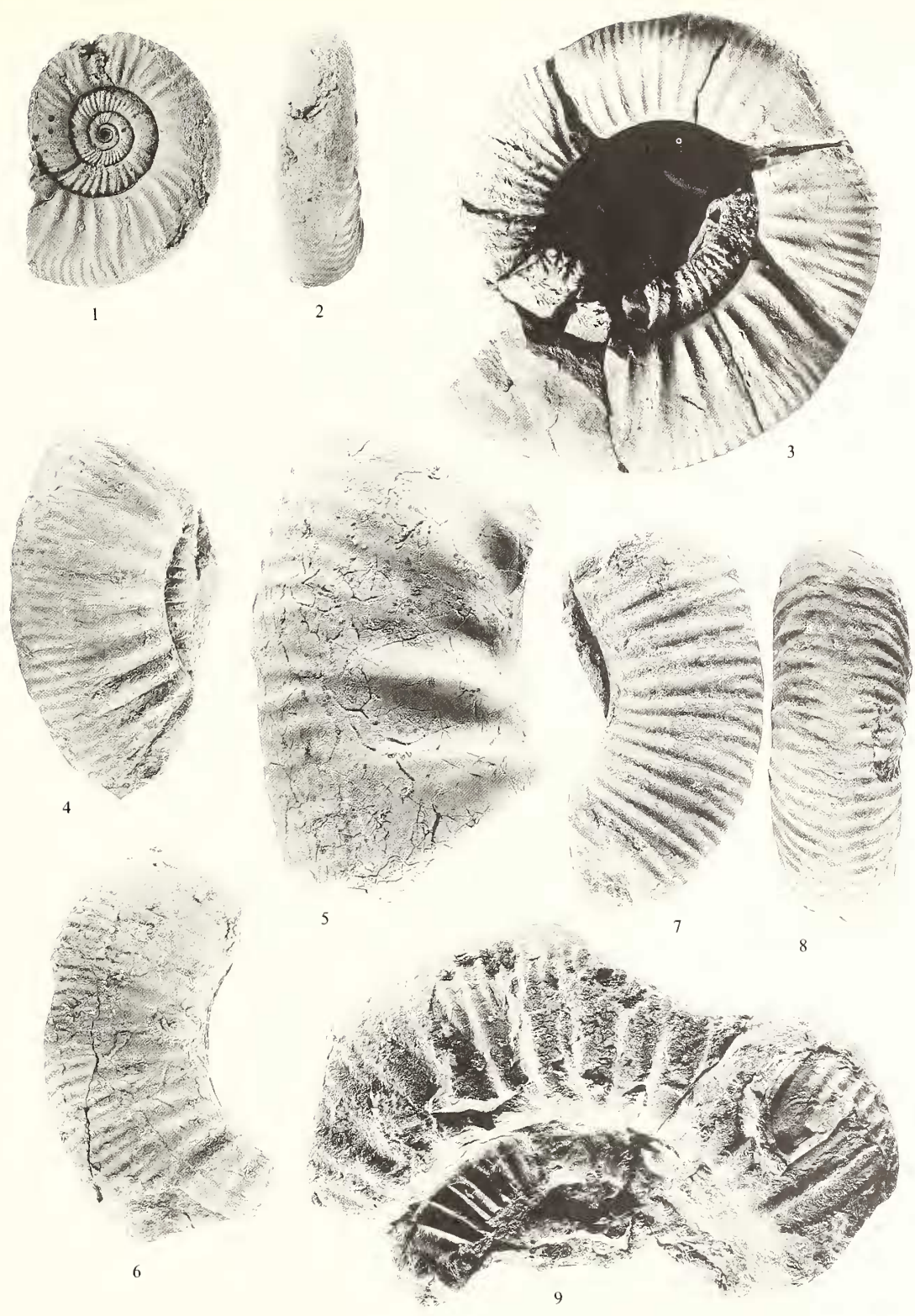
WESTERMANN and WANG, *Choffatia*

Age and distribution. L. *funata* is known from the entire Lower Callovian of Europe (Mangold 1970), and the highest Lower Callovian of Madagascar (Collignon 1958). Similar forms were also described from the 'sub-*anceps* beds' of Kachchh (Spath 1927–1933).

<div align="center">

Subgenus CHOFFATIA (INDOSPHINCTES) Spath, 1930
Choffatia (*Indosphinctes*) aff. *urbana* Spath, 1931

</div>

v 1979   *Kellawaysites* sp.; Wang and Chen *in* Wang *et al.*, p. 59, pl. 17, fig. 10.

Material. Specimen NIGP 34076 from loc. 12.

Description. The shell is somewhat involute and has a compressed subelliptical whorl-section with rounded venter. The flanks have rather dense ribs which mostly trifurcate at different height on the inner flank and cross the venter.

Discussion. This specimen resembles *C. urbana* from the 'upper *Macrocephalus* beds' of Kachchh (Spath 1931, p. 340, pl. 81, fig. 1) in its small umbilicus and the division of the blunt primary ribs low on the flank.

Age and distribution. The species had only been described from the Calloviense/Gracilis Zone of Kachchh, but similar forms occur abundantly in the upper Lower Callovian of western Europe (Mangold 1970).

<div align="center">

Choffatia (*Indosphinctes*) sp.

</div>

v 1976   *Choffatia madani* Spath; Zhao, only pl. 8, figs. 3 and 4.

Material. Fragment NIGP 30452 from bed Kp18 of loc. 10.

Remarks. This fragment has an ovate whorl-section and the blunt ataxiocerid ribbing on the inner flank characteristic of this late Early Callovian subgenus.

<div align="center">

Subgenus GROSSOUVRIA Siemiradzki, 1898
Choffatia (*Grossouvria*) *propinqua* Uhlig, 1910 ♂

Plate 25, figs. 1–2

</div>

* 1910   *Perisphinctes* (*Grossouvria*) *propinquus* Uhlig, p. 287, pl. 44, fig. 5*a*, *b*.

Material. One almost complete microconch, J2184, phragmocone as mould (latex cast), from bed A5 of loc. 13.

Description. The last phragmocone whorl of our specimen is subcircular, but, as in the holotype, the body-chamber becomes compressed-ovate. The primary ribs of the phragmocone are dense and strongly prorsiradiate, and there are several deep constrictions with similar inclination. The body-chamber of which almost three-quarters of a whorl are preserved, has distant, irregular primaries, several of them parabolic, which divide at about three-fifth whorl height into two or three secondaries. The secondaries are straight on the venter of the first half of the body-chamber, probably with some flattening in the siphonal region, but become markedly curved backward and interrupted on the ultimate quarter whorl. Several ventrolateral clavi are also present. The presence of lateral lappets is indicated by lateral rib geniculation.

Discussion. Our specimen from the '*Grayiceras*' Association closely resembles the holotype (monotypy) of Uhlig's species from the lower Spiti Shales of Chikkim, Niti. There is good agreement with *Perisphinctes curvicosta* of Waagen (1875, pl. 39, fig. 4 only; refigured by Spath 1931, pl. 60, fig. 8) from the '*anceps*-beds' of Jumara, and also with *C.* (*Grossouvria*) *koutkiewiczi* (Siem.) from the Middle Callovian of Europe (Mangold 1970, pl. 8).

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